NASA Tech Briefs

Transferring Technology to American Industry and Government

November 1989
Volume 13 Number 11

Tomorrow's Space Worker

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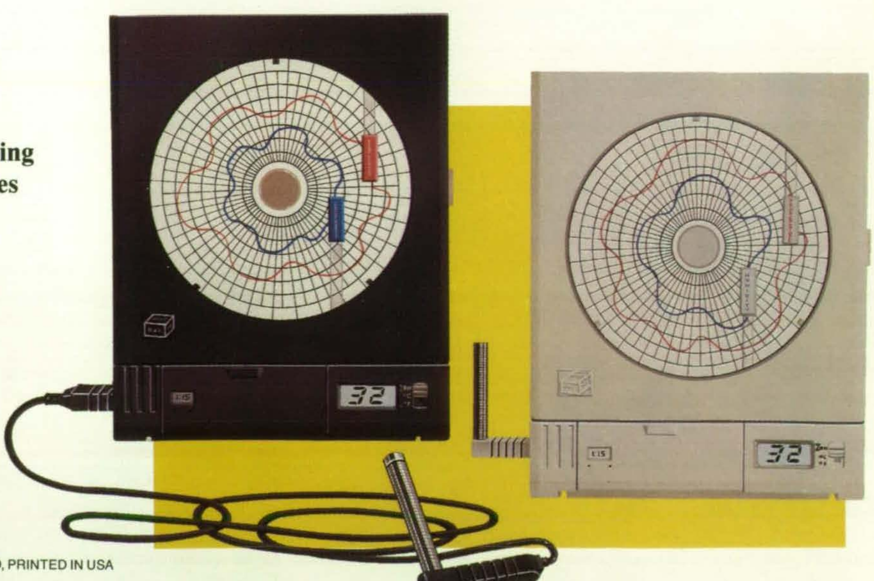
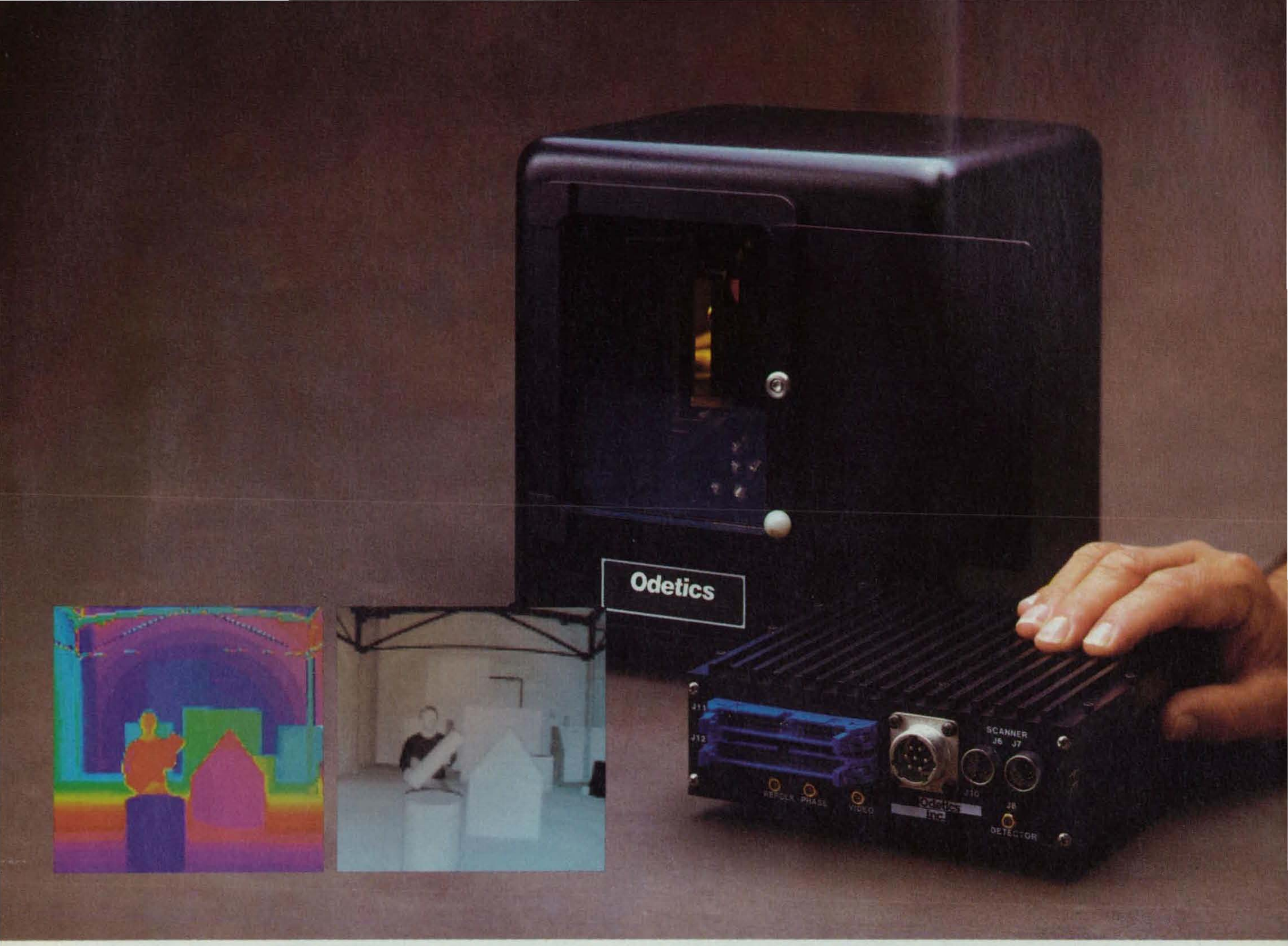
& Make Them Even Better™





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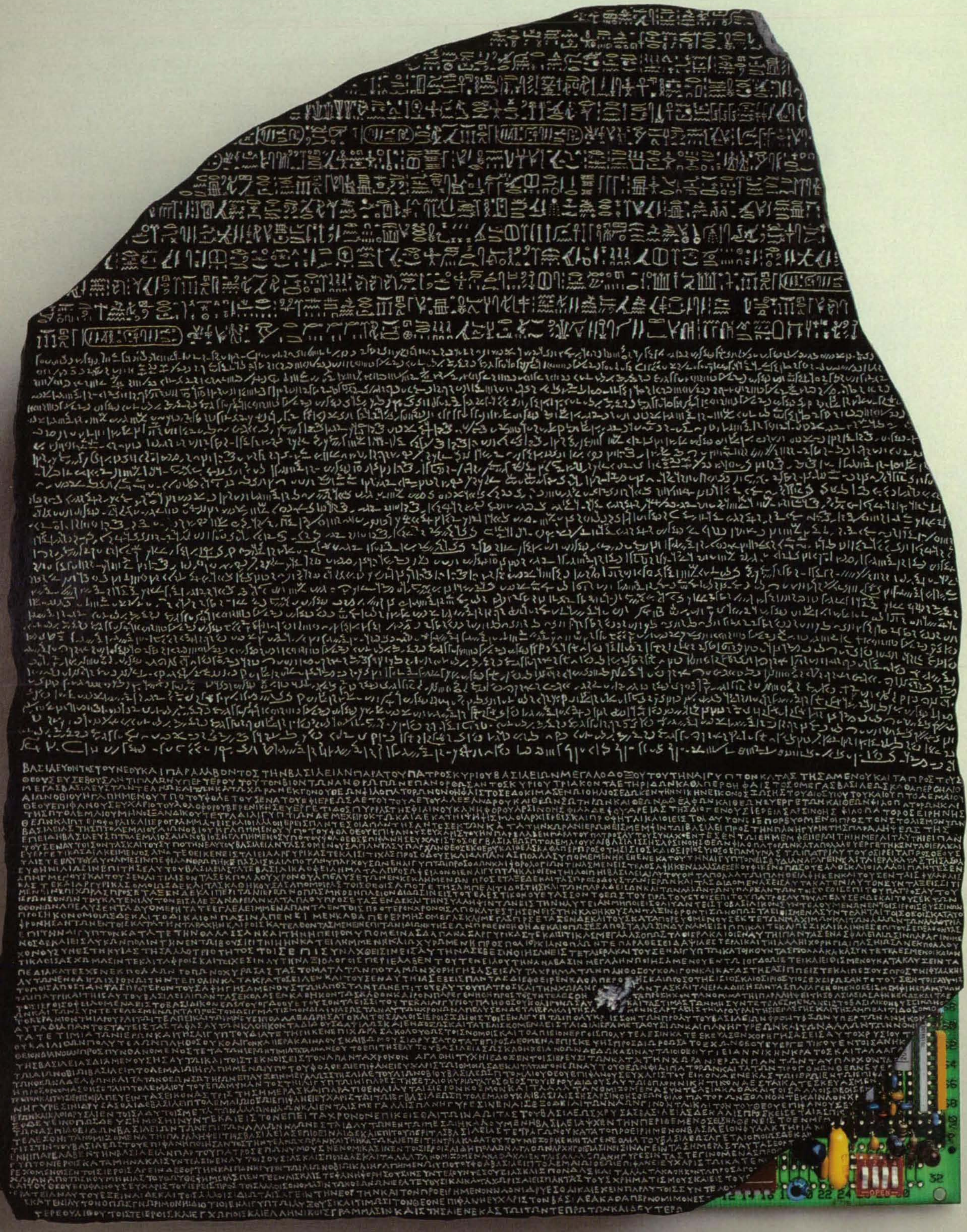

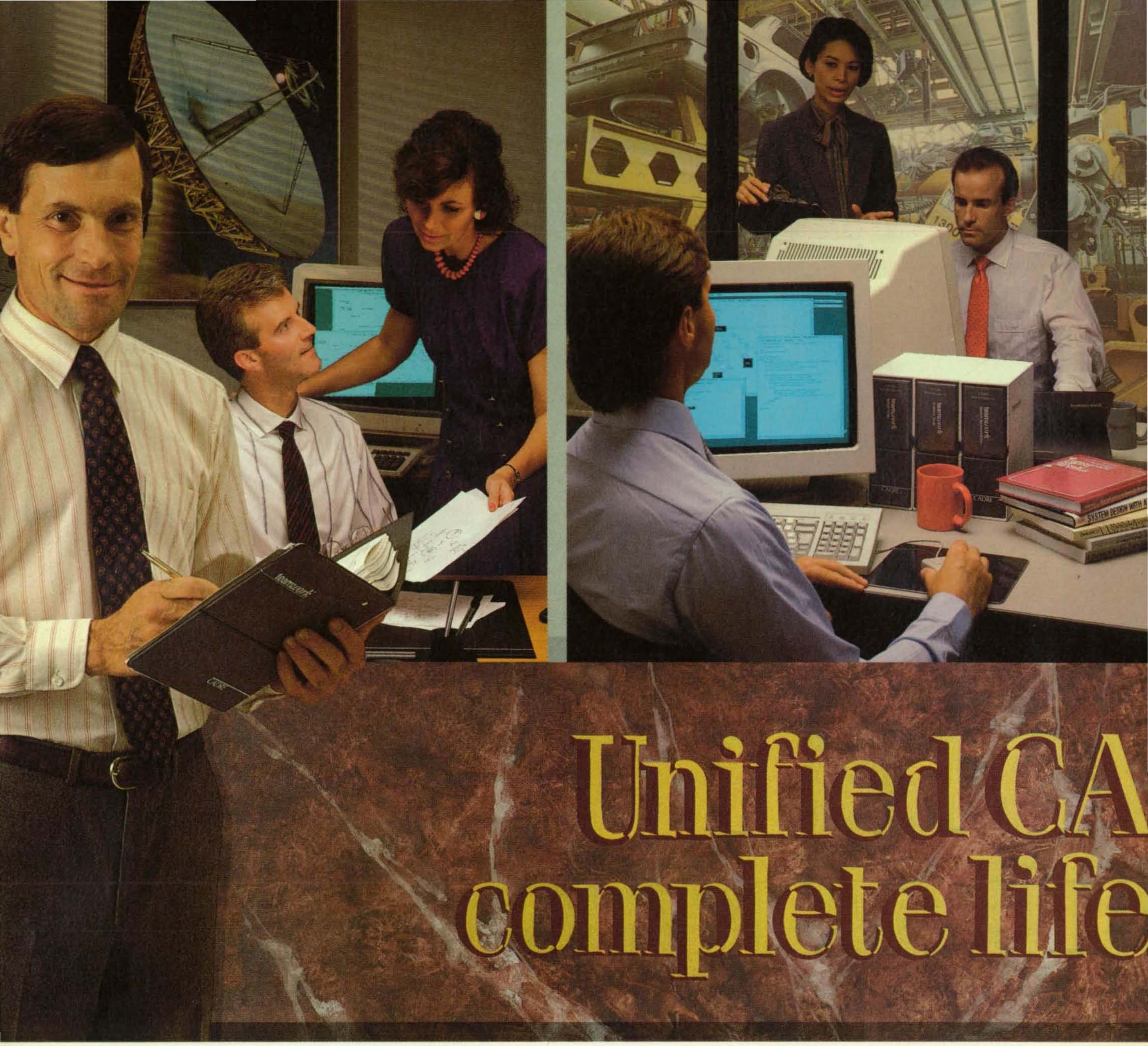

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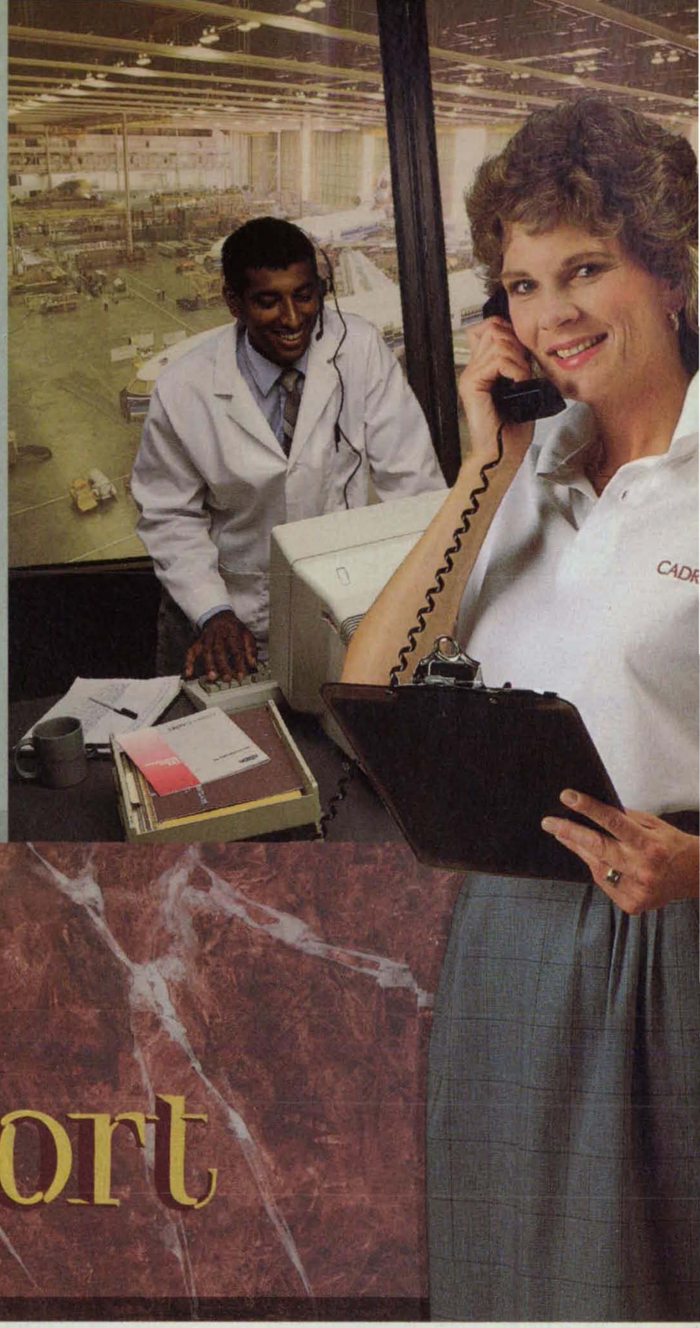

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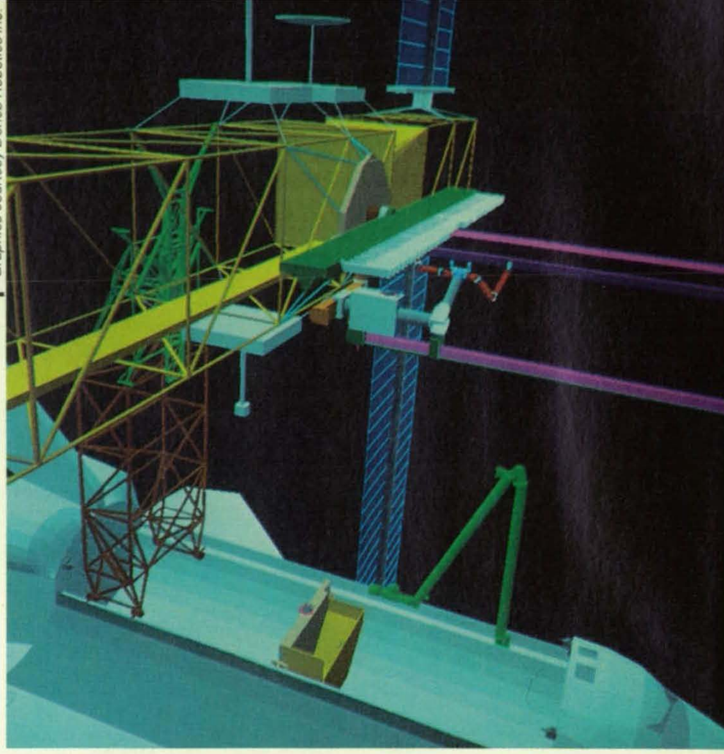

Graphics courtesy Deneb Robotics Inc.

SPECIAL FEATURE

NASA researchers are using a new CAD system called the Graphic Robot Simulator to develop and study robotic tasks for space station Freedom. The Simulator applies advanced engineering concepts to evaluate operational problems that might occur while performing a task on the station or in the ground test environment. ***See page 14.***

TECHNICAL SECTION

DEPARTMENTS

On The Cover: Computer simulation shows the Flight Telerobotic Servicer assembling a portion of the U.S. space station. The highly dexterous robot will help astronauts build the station, maintain attached payloads, and service visiting spacecraft. Artificial intelligence programming will enable the robot to "think" like a human and carry out complex tasks after receiving a single command from an astronaut. *(Graphics courtesy Deneb Robotics Inc., Troy, MI)*

NASA's Goddard Space Flight Center has unveiled a state-of-the-art robotics facility that will play a key role in developing robot workers for future space missions. ***Turn to page 14.***

Photo courtesy NASA

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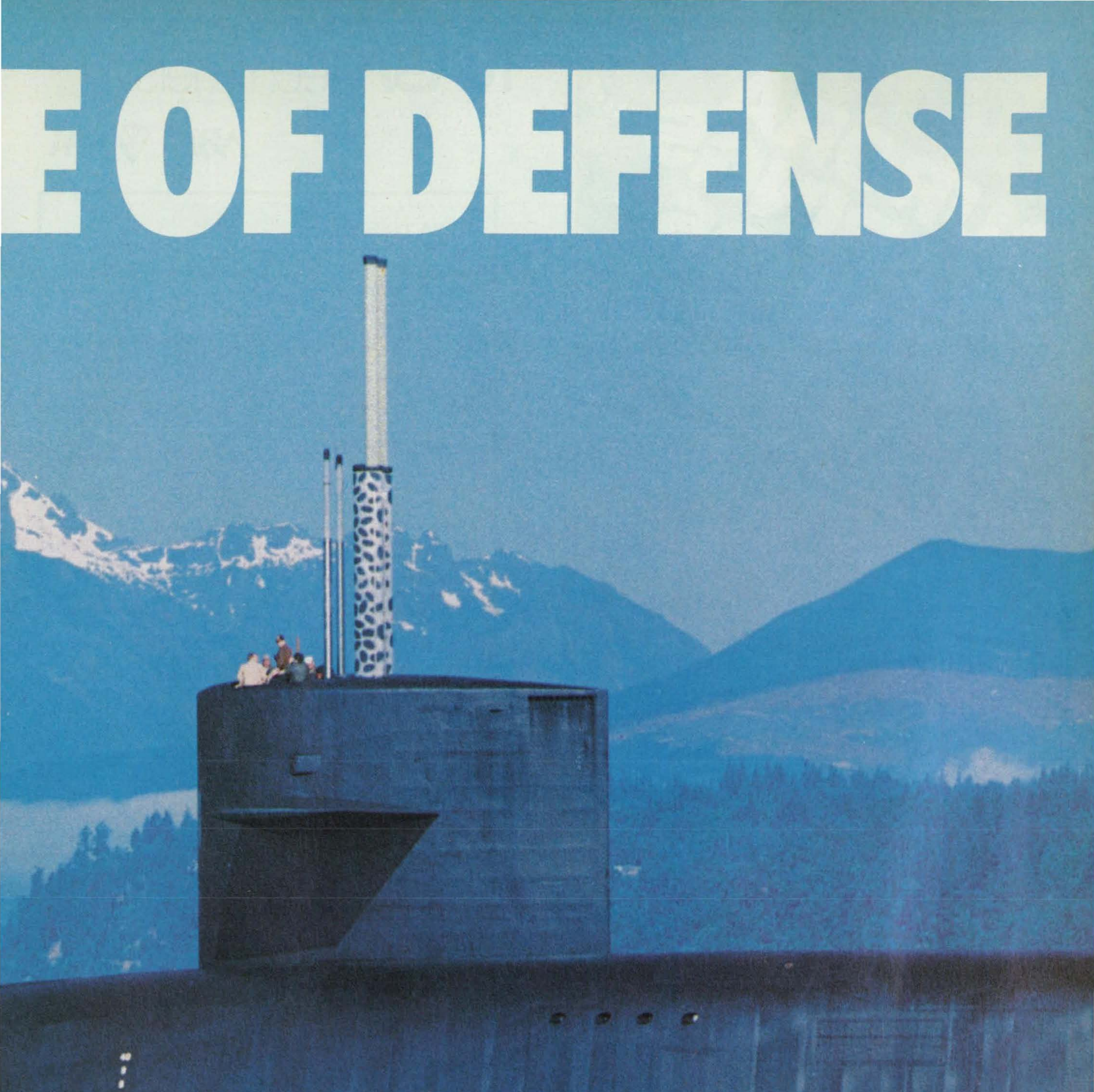

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New Product Ideas

New Product Ideas are just a few of the many innovations described in this issue of *NASA Tech Briefs* and having promising commercial applications. Each is discussed further on the referenced page in the appropriate section in this issue. If you are interested in developing a product from these or other NASA innovations, you can receive further technical information by requesting the TSP referenced at the end of the full-length article or by writing the Technology Utilization Office of the sponsoring NASA center (see page 18). NASA's patent-licensing program to encourage commercial development is described on page 18.

Tool Distributes Clamping Load

A tool distributes a clamping load stably and fairly evenly among five clamping feet. The tool was designed to stabilize and even out the pressure applied to foam pads during bonding and can also be used in other situations where it is necessary to maintain fairly even clamping loads during fabrication processes. (See page 64).

Robotic Target-Tracking Subsystem

A robotic vision subsystem measures the relative position and orientation of a specially designed target. The subsystem could be useful in industrial assembly operations that require automatic joining of parts that are initially oriented and moving randomly. (See page 36).

Improved Transparent Furnace for Crystal-Growth Experiments

A very uniform coil spacing assures better visibility and control of conditions in an improved transparent furnace used for crystal-growth experiments. The furnace features slotted quartz spacer rods used to hold the heating coil accurately on the inside of a quartz tube. (See page 68).

Making a Noble-Metal-on-Metal-Oxide Catalyst

A two-step process prepares a platinum- or palladium-on-tin-oxide catalyst for the recombination of CO and O_2 decomposition products that occur in the high-voltage discharge region of a closed-cycle CO_2 laser. This process is also applicable to other noble-metal/metal-oxide combinations. (See page 52).

Multihole Arc-Welding Orifice

A modified orifice for variable-polarity plasma-arc welding directs the welding plume so that it creates clean, even welds on aluminum alloys. The orifice includes eight holes to relieve the back pressure in the plasma. (See page 73).

Cooling Shelf for Electronic Equipment

A system uses heat-pipe action to cool and maintain electronics at nearly constant temperature in spacecraft. Besides its use in aerospace applications, this technology is potentially useful in freeze drying, refrigeration, and air conditioning. (See page 59).

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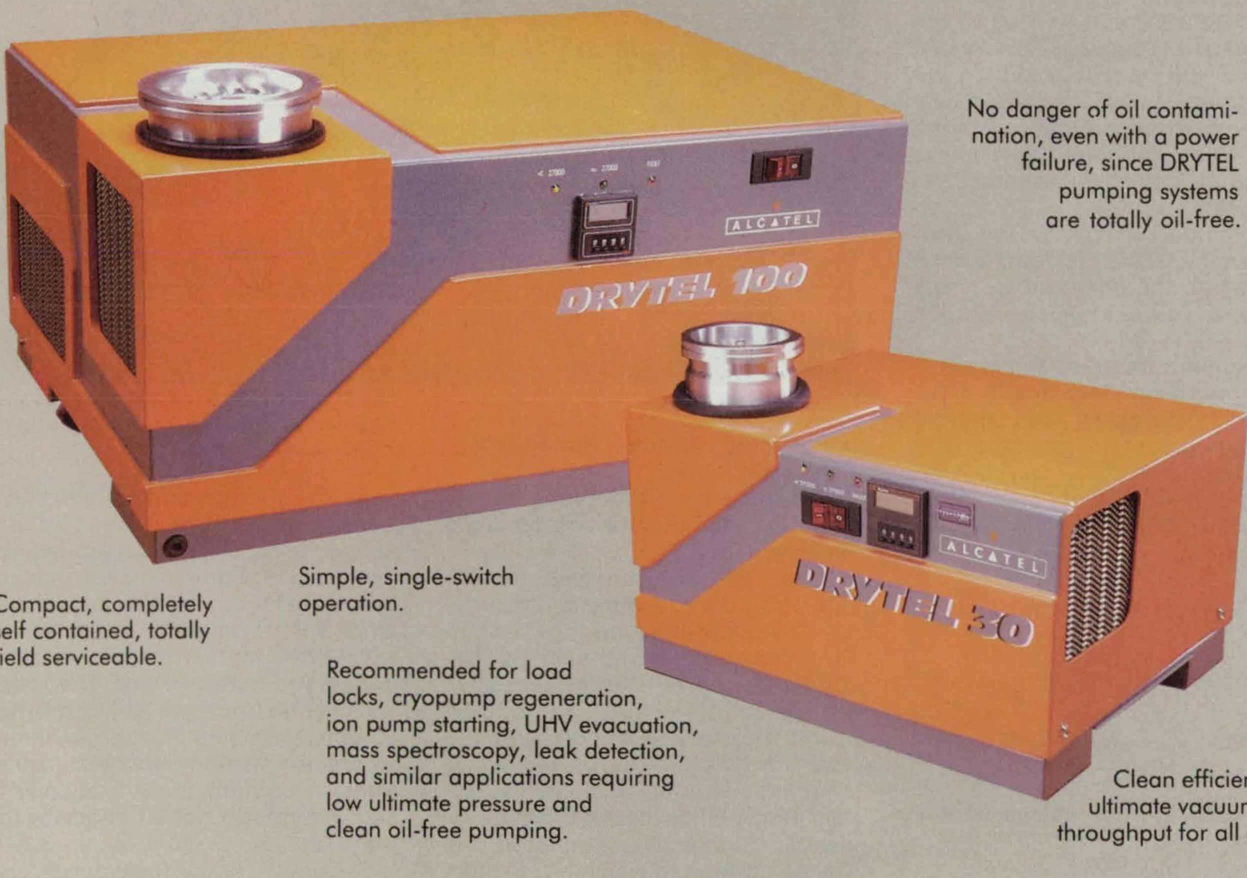

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The Flight Telerobotic Servicer: Tomorrow's Space Worker

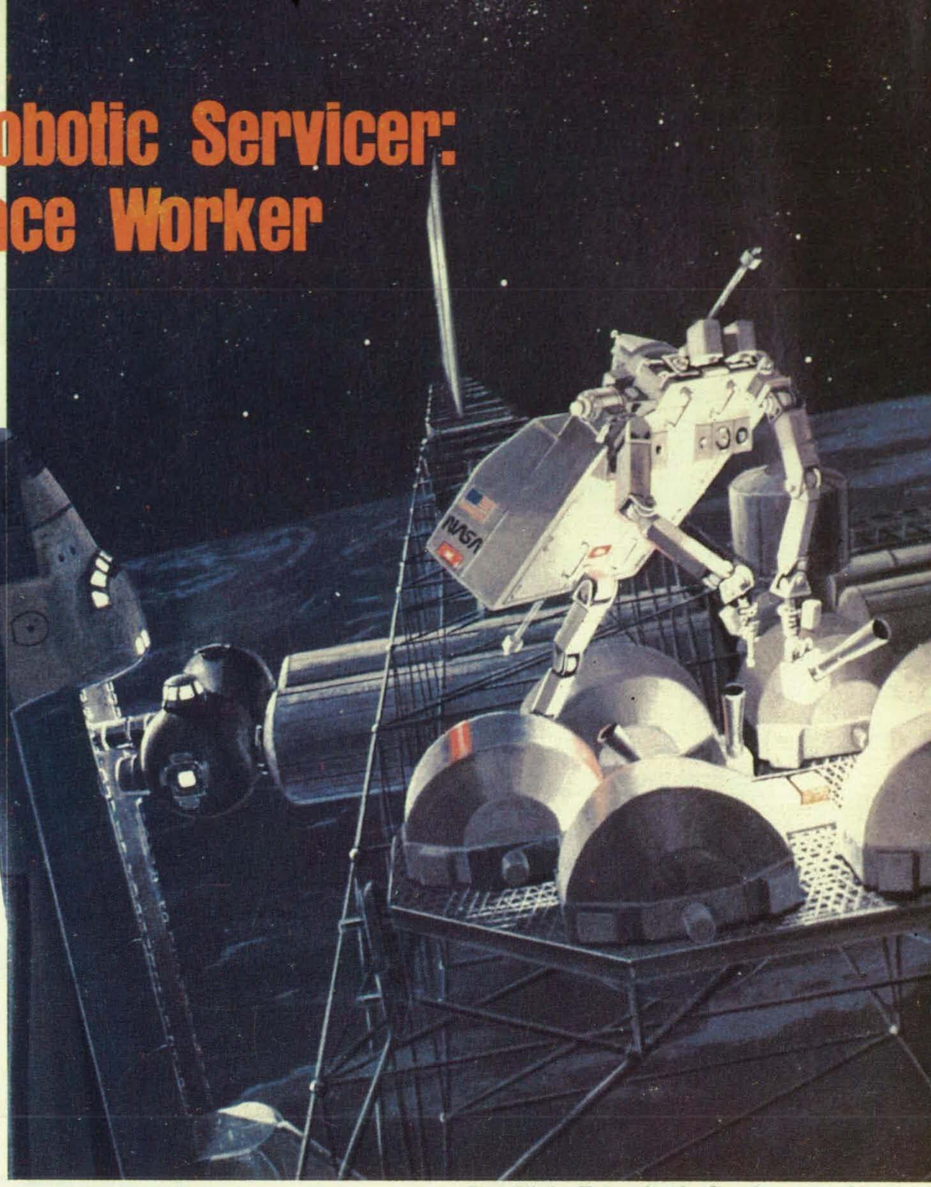


Illustration Courtesy NASA

The Flight Telerobotic Servicer repairs a component on the Freedom station in this artist's concept.

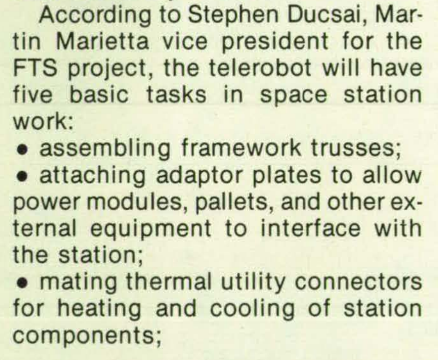
America's first full-time construction worker in space will be a one-legged, two-armed robot with "eyes" on its wrists.

Called the Flight Telerobotic Servicer (FTS), the six-foot-tall robot will help astronauts build space station Freedom in the mid-1990s. The FTS will combine teleoperation — the use of a human operator to direct the machine — and autonomous capabilities for performing tasks on its own but under an astronaut's supervision.

Martin Marietta Space Systems is developing the FTS under a $303 million contract from NASA's Goddard Space Flight Center. As part of the development program, FTS mechanical arms will be tested aboard the space shuttle in 1991, followed by a 1993 demonstration flight of the prototype robot. The final flight unit is slated for launch on the second Freedom assembly mission.

According to Stephen Ducsai, Martin Marietta vice president for the FTS project, the telerobot will have five basic tasks in space station work:

- assembling framework trusses;
- attaching adaptor plates to allow power modules, pallets, and other external equipment to interface with the station;
- mating thermal utility connectors for heating and cooling of station components;
- replacing run-down batteries and power modules;
- installing the 50-foot-long panels that comprise the orbiting facility's heat radiators.



The FTS will feature highly dexterous arms for delicate maneuvers and stereo cameras for vision. Its torso will house a computer, power converters, and data management and communications equipment.

"The FTS will enable astronauts to direct routine assembly and maintenance work without leaving the shuttle or space station," said Ducsai, "thereby increasing crew productivity and safety."

Initially, the FTS will be carried to and from work sites by the space shuttle's Remote Manipulator System (RMS). Once the early station assembly flights are completed, the Canadian Mobile Servicing System (MSS) will assume this job. The FTS will operate while attached to the MSS mechanical arm, but will derive additional stability by clamping its leg to a handy portion of the station. The telerobot will be able to handle objects with masses up to 1200 pounds; larger masses will be moved by the host transporter, with the FTS aiding in final alignment and positioning.

Both FTS manipulator arms will have seven degrees of freedom, enabling the robot to reach around objects and perform delicate maneuvers. Connectors at the end of the arms will accommodate a variety of specialized tools, from wrenches to grippers to screwdrivers. The robot will change from one tool to another automatically and perform extremely precise movements with those tools, according to James Lowrie, Martin Marietta's chief engineer for the FTS.

"The servicer will have only a five-thousandths-of-an-inch variation in repeatability," he said. "In other words, we can place the arm in one position, then move it away and bring it back to the same position with a tolerance far smaller than a human hair."

In addition, the arm will be able to use the tools to make adjustments in increments as small as one-thousandth of an inch.

Teaching The Machine To Think

At first, astronauts will operate the FTS remotely from inside the shuttle or space station, employing six-degree-of-freedom hand controllers to direct its movements while viewing video images of the work site captured by voice-controlled cameras attached to the robot's head and wrists. The hand controls will be sensitive enough to allow astronauts to feel the amount of force the mechanical arms are using. "In tests, operators have actually been able to feel the grain of a sheet of plywood when the robot arm moves across it," Lowrie said.

Eventually, the goal is to use artificial intelligence (AI) computer programming to enable the robot to "think" its own way through complex tasks after receiving a single command from an astronaut. These tasks might include inspecting areas of the station or replacing spacecraft parts.

"We'll need to teach the robot to observe the work site and, through its onboard computer, extrapolate what it sees into a computer-aided design model," explained Lowrie. From there, the AI program will enable the robot to compare what it sees with models already in the computer and plan a sequence of operations to complete a job.

Once this level of autonomy is achieved, NASA plans to mount the FTS on an Orbital Maneuvering Vehicle that will travel to remote spacecraft in need of fuel or repairs. Explained Stanford Ollendorf, chief of Goddard's Telerobotic Engineering Office: "The FTS would be able to retrieve and service satellites such as polar platforms which are currently beyond the reach of the space shuttle, saving millions of dollars annually."

Flexible Space Systems

The FTS project is NASA's response to a mandate from congress to advance the state of the art in robotics. The congressional directive resulted in the formation of the NASA Advanced Technology Advisory Committee (ATAC), which concluded that "a key element of technology for the space station is extensive use of advanced general-purpose automation and robotics." This could lead to the development of flexible and adaptable space systems, the ATAC argued, which would be important for nurturing commercial space applications.

NASA views the FTS as an essential step in creating more sophisticated autonomous robots that will support human exploration of Mars or the construction of a lunar base in the next century. "In addition to its role in assembling space station, the (FTS) will serve as a space test bed for new robotic and telepresence technologies as they evolve," said Ollendorf. The FTS control system architecture, called NASREM, allows for incremental evolution as technology advances. Developed at the National Institute of Standards and Technology, NASREM defines a set of standard modules and interfaces that can be implemented with many different computer hardware and software configurations. "This architecture will enhance our efforts to standardize robot development," Ollendorf stated, "and will facilitate technology transfer to industry."

With NASREM, the FTS will "create a kind of center of gravity for the robotics industry," said John Oberright, FTS project manager at Goddard. "To this point, the communication of design concepts within industry has been helter-skelter because everyone uses different terms to describe the same functions. NASREM will establish a common reference terminology for various robot systems, so that people can better communicate and work together."

Goddard's High-Tech Test Bed

This summer, Goddard unveiled a state-of-the-art space robotics facility which will be used to create, integrate, and test new technologies for the FTS project. "The primary function of the facility," said Ollendorf, "is to provide input to the FTS contractor in areas of high risk, such as controls and safety, thereby reducing research and development costs."

The facility features a gantry robot 40 feet wide, 60 feet long, and 20 feet high capable of lifting up to two

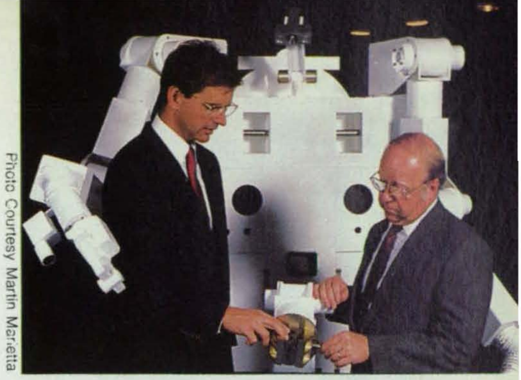


Photo Courtesy Martin Marietta

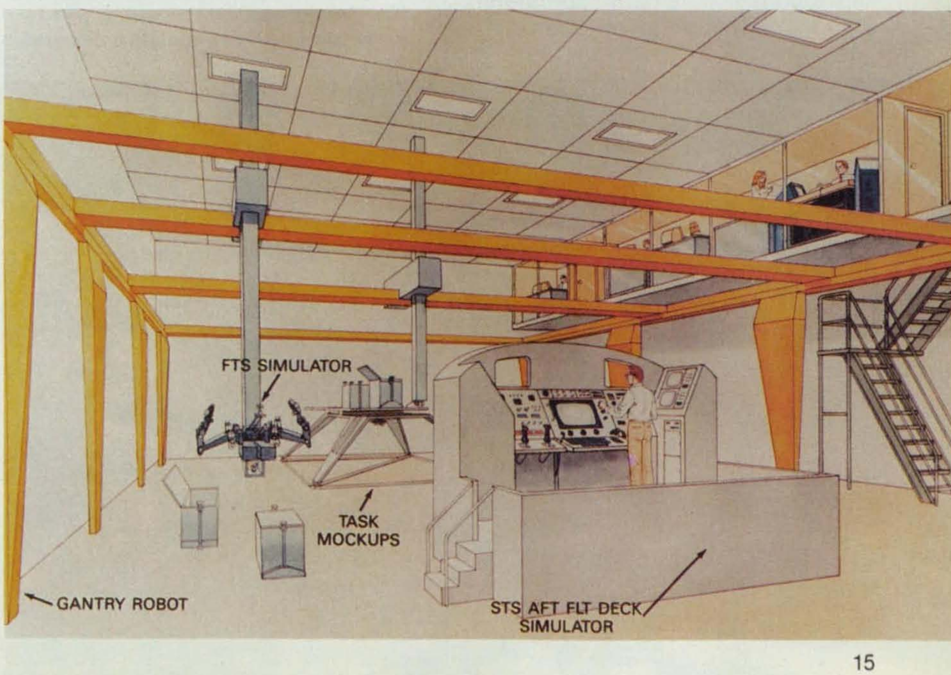
Martin Marietta's James Lowrie (left) discusses the design of an FTS robot "hand" with Ronald Browning, Goddard's deputy director for space station.

tons of payload and applying 4000 foot-pounds of torque. Suspended from one gantry mast is a set of six-degree-of-freedom industrial arms which serves as an FTS operational simulator. A second mast carries a grapple to emulate the Remote Manipulator System. Goddard's robotics team uses these devices to study tasks such as robotic removal of an Orbital Replacement Unit (a generic housing for space station experiments) and assembly of large instruments.

Next to the gantry is a mockup of the shuttle's aft flight deck containing an operator workstation for remote control of the mechanical arms. The mockup will help researchers determine the best positioning of hand controllers and displays in the confined space of the shuttle.

Goddard has developed a unique computer graphics system for the test facility that simulates each movement a robot would make in space. "It helps us determine things

Illustration of Goddard's new space robotics facility



Goddard researcher uses force-reflecting hand controllers to manipulate robot arms. Forces and torques sensed at the slave manipulator are fed back to the master hand controller and felt by the operator.

like the robot's reach capability and provides valuable information on collision avoidance," explained David Provost, who heads Goddard's Robotics Data Systems and Integration Section. The system, dubbed the Graphic Robot Simulator, can be configured to allow the teleoperator to drive a computer model of the slave arms using the actual master arms. This approach offers a quick and safe means to test new control strategies or watch task sets being completed. Upon completion of a successful scenario, commands can be downloaded to the robot to perform the task autonomously.

"The simulator reduces construction costs considerably for spacecraft and instrument subsystems," said Provost, "and makes results available in a much shorter time."

The new facility also contains a pair of teleoperated seven-degree-of-freedom manipulators for studying control methods, end-effector designs, safety systems, and sensor technologies. In one experiment, Goddard engineers are growing a sensor-lined skin for the robotic arms that will enable an operator to determine the robot's proximity to other objects. Another effort focuses on developing a multi-level, computerized safety system for telerobotic control. The primary level, known as the Watchdog Safety System, monitors robot joint positions, motor currents, and joint torques to ensure that these readings are within safe limits. If the preprogrammed limit is exceeded, the computer will shut the robot down.

Meanwhile, a higher level "expert" system watches over each step of the task, making sure proper procedures are followed. If the operator skips a step, a synthesized voice will advise him to stop and analyze the situation.

"Over the coming years we'll gradually be adding more artificial intelligence into the robot system," Provost said. "We're working towards the creation of a truly autonomous robot, one that will pick up a tool on its own and know where to go and what to do to fix a spacecraft part. But that's the future; right now our main concern is getting the teleoperated FTS ready to fly." □

The FTS will be transported by the manipulator arm on the Canadian Mobile Servicing System, which will be mounted on the space station's trusswork.

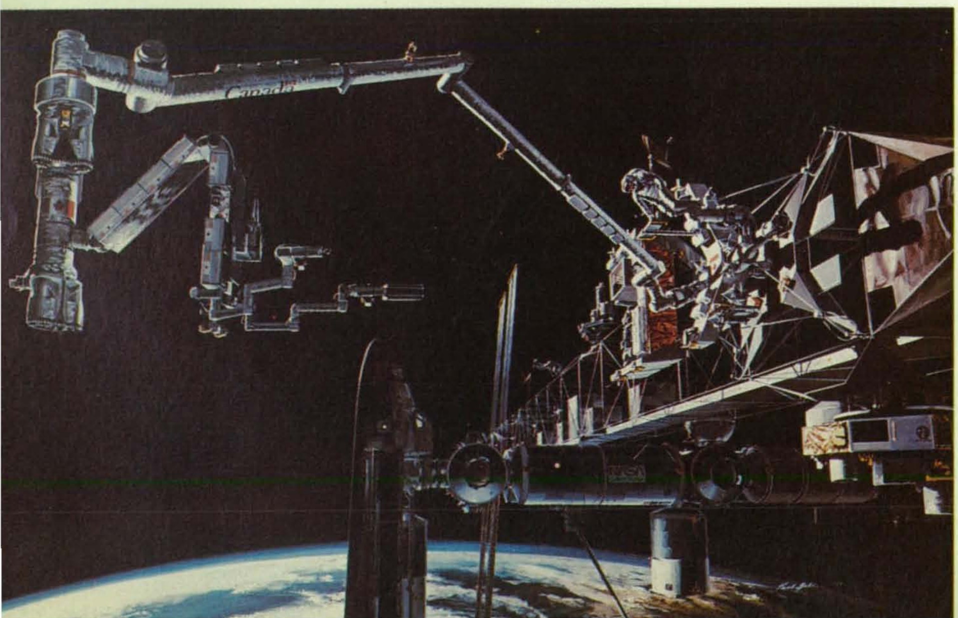


Illustration courtesy NASA

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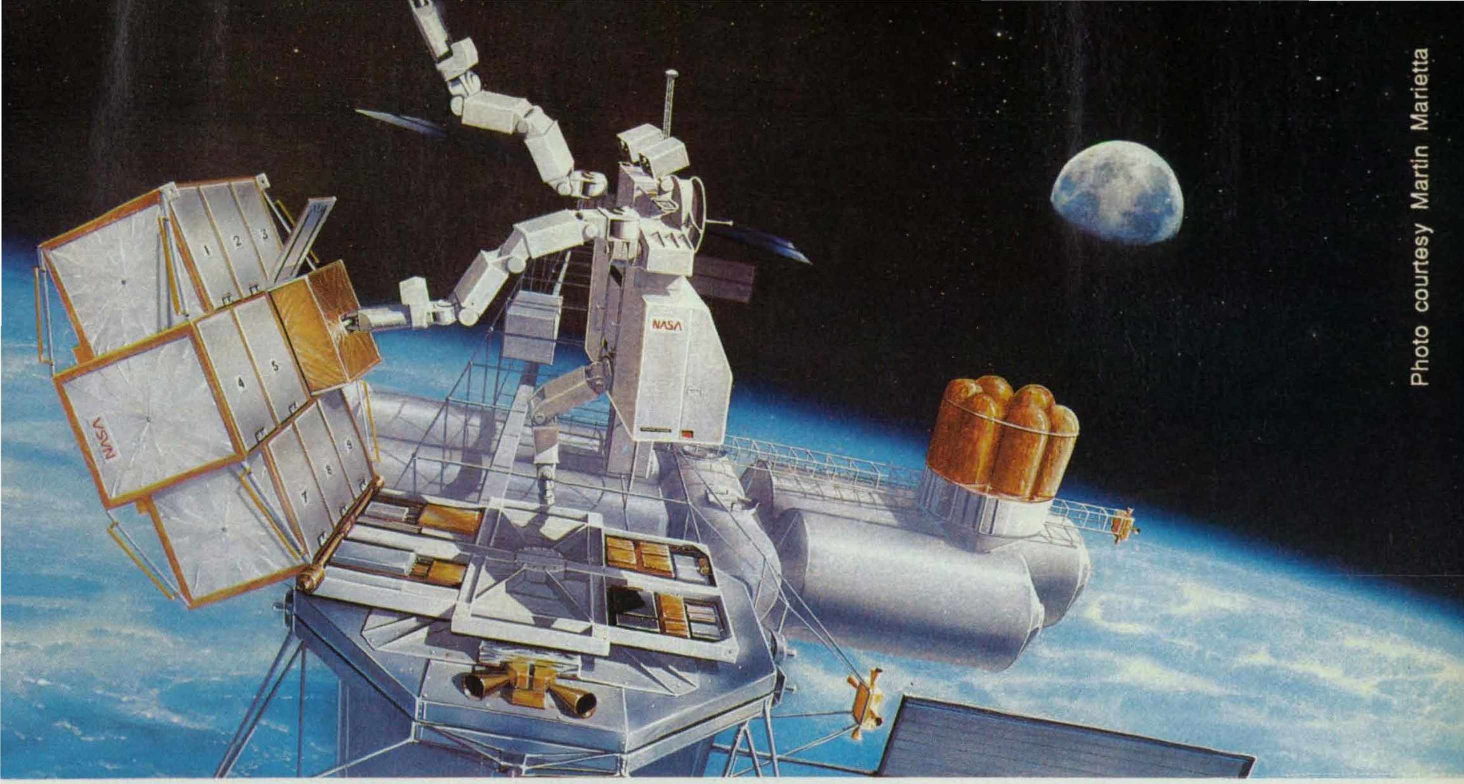


Flight Telerobotic Servicer

Electronic Components and Circuits

Electronic Rotator for Sheet of Laser Light

A sine/cosine potentiometer is used to orient two galvanometer/mirror devices simultaneously.

Langley Research Center, Hampton, Virginia

The primary flow-visualization system in the Basic Aerodynamic Research Tunnel (BART) at NASA Langley Research Center is a sheet of laser light generated by a 5-W argon-ion laser and a two-axis mirror galvanometer scanner. The system generates single and multiple sheets of light, which can remain stationary or be driven to sweep out a volume.

A feature not directly achievable with the original version of this system was the ability to rotate a single sheet of light through 360°. Several schemes to accomplish this rotation were investigated and ruled out as too complex or time consuming. However, the use of a sine/cosine potentiometer — an approach based on technology developed in the early 1940's to generate plan-position-indicator (PPI) displays for radar systems — yielded the desired result at reasonable cost and was incorporated into a prototype in 1 day.

Figure 1 is a simplified layout of the BART two-axis laser-light-sheet system. If a sinusoidal waveform is applied to the *Y* galvanometer, a vertical ($\theta = 0°$) sheet of light is formed as the laser beam is repeatedly scanned through a vertical arc. If the sine wave is applied only to the *X* galvanometer, a horizontal ($\theta = 90°$) sheet of light is formed. To generate a sheet of light at any angle θ, the *X* galvanometer should be fed a signal equal to the input sine wave times sin θ, and the *Y* galvanometer should be fed a signal equal to the input sine wave times cos θ. In practice, the input is a sawtooth or triangular waveform instead of a sine wave. The use of linear waveforms yields a fanned beam of uniform intensity, whereas a sinusoidal waveform produces a sheet of light that is brighter at the edges than at the center, following the probability distribution of the input signal.

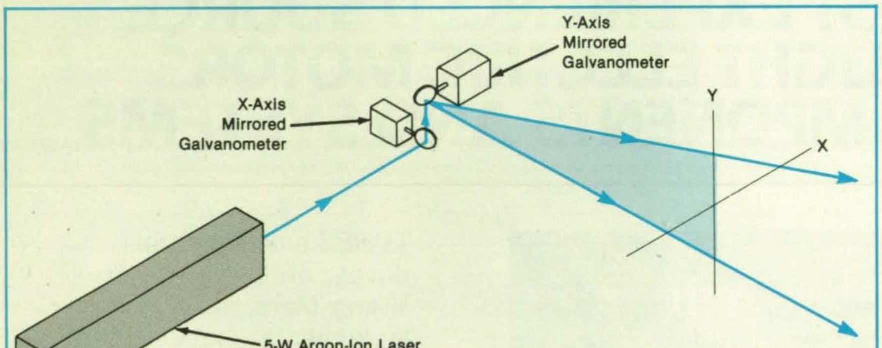


Figure 1. **Two Mirrored Galvanometers and an Argon-Ion Laser** generate sheets of laser light.

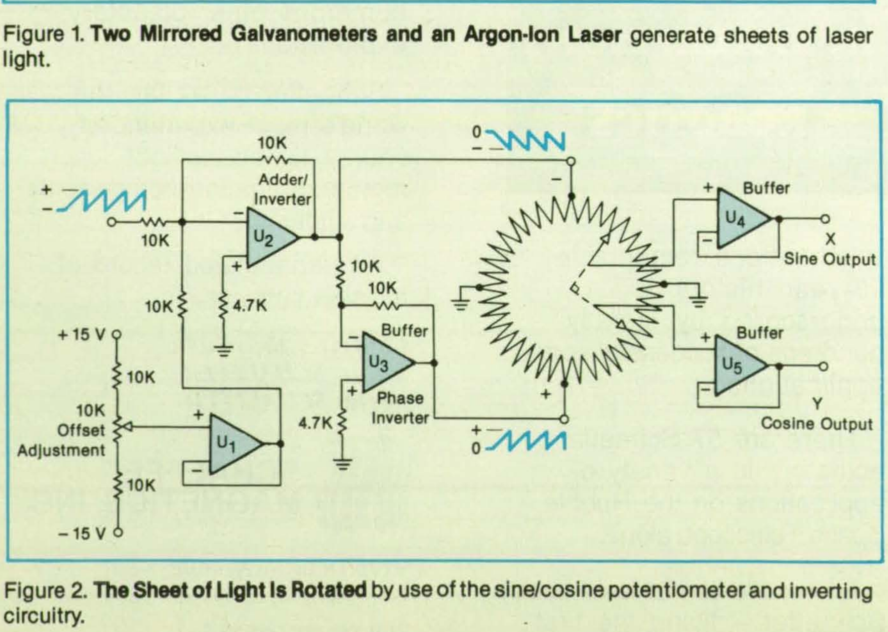


Figure 2. **The Sheet of Light Is Rotated** by use of the sine/cosine potentiometer and inverting circuitry.

The schematic diagram of the electronics used to rotate the light sheet is shown in Figure 2. The input waveform is combined with a buffered variable offset and inverted with amplifier U_2. Amplifier U_1 is a high-impedance, unity-gain buffer. Amplifier U_3 is another unity-gain inverter and is used to generate a negative replica of the output of U_2. The outputs of U_2 and U_3 are fed to the + and − end contacts of the sine/cosine potentiometer. Since the + and − signals are of the same shape but opposite in polarity, the center taps are at 0 V and are connected to ground. The sine and cosine outputs are buffered with high-impedance, unity-gain amplifiers U_4 and U_5. The buffered outputs are connected to the *X* and *Y* galvanometer drivers.

The prototype was tested by substituting the *X* and *Y* inputs of an oscilloscope for the galvanometers. If the oscilloscope is left connected to the *X* and *Y* outputs while the galvanometers are connected, the oscilloscope can be used to monitor remotely the position of the sheet of light in real time. Subsequent testing was performed, and the completed unit is in full operation at the BART facility.

This work was done by John M. Franke, David B. Rhodes, Bradley D. Leighty, and Stephen B. Jones of **Langley Research Center**. *No further documentation is available.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 18]. Refer to LAR-13836

Biomedical Telectrodes

Compact transmitters would eliminate the need for wires to monitors.

Lyndon B. Johnson Space Center, Houston, Texas

Biomedical telectrodes have been proposed for the transmission of physiological measurements to monitoring equipment. A biomedical telectrode would be a small electronic package containing a sensing device — for example, a pair of electrodes in contact with the body, a single electrode with terminals for wire connections to electrodes elsewhere on the body, or a thermometer. The package (see Figure 1) would also contain signal-conditioning circuitry to process the signals picked up by the sensing devices, a small radio transmitter, and a small battery. The design of the biomedical telectrode would take advantage of the recent advances in the fabrication of integrated circuits and the technologies of batteries and sensors.

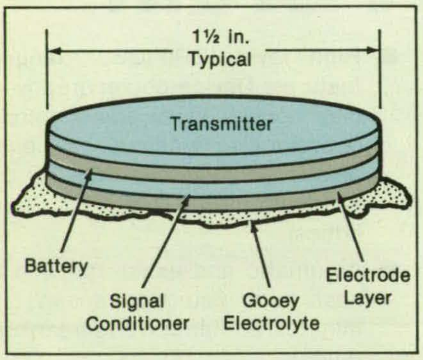


Figure 1. A **Biomedical Telectrode** would be a small electronic package that could be attached to the patient in a manner similar to that of a small adhesive bandage.

The principal advantages of biomedical telectrodes are that they would be relatively unobtrusive and that they would allow the patient (or animal subject under investigation) to move freely, without risk of entanglement in wires connected to monitoring equipment, and without fear of accidental disconnection of wires. These features would be especially beneficial to patients undergoing electrocardiographic monitoring in intensive-care units in hospitals; they would eliminate the accidental disconnections that occur when patients roll over wire electrode connections and pull them out while sleeping. They would also eliminate the nuisance of coping with wire connections while dressing and going to the toilet.

The design of the signal-conditioning integrated circuit in a biomedical telectrode would depend on the signal to be measured. The power supply would be designed so that the device would not be activated until attached to the patient and would be deactivated when detached. The telectrode would transmit at a fixed frequency. If a set of telectrodes were to be used on a patient, each would transmit at a different frequency. A label on the telectrode package would state the type of internal circuitry (or the type of signal to be sensed and transmitted) and the frequency of the transmitter.

This work was done by C. K. Shepherd of Lockheed Engineering and Sciences Co. for **Johnson Space Center**. *For further information, Circle 29 on the TSP Request Card.*
MSC-21501

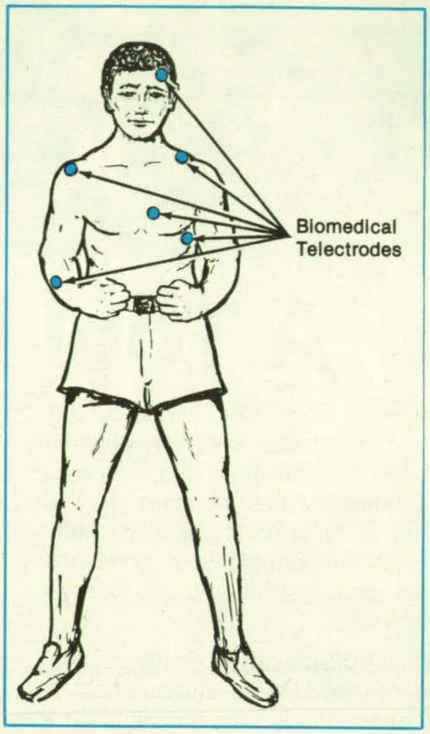


Figure 2. A **Patient Wearing Biomedical Telectrodes** could move freely, without risk of breaking or entangling wire connections.

Variable-Resistivity Material for Memory Circuits

Nonvolatile memory elements can be packed densely.

NASA's Jet Propulsion Laboratory, Pasadena, California

Electrically-erasable, programmable, read-only memory matrices can be made with a newly-synthesized organic material of variable electrical resistivity. The material — polypyrrole doped with tetracyanoquinhydrone (TCNQ) — changes reversibly between an insulating or higher-resistivity ("off" or "zero") state and a conducting or low-resistivity ("on" or "one") state. The matrix circuits made with this material are useful for experiments in associative electronic memories based on models of neural networks.

Each memory cell is a variably resistive connection in the small portion of the film at the intersection of a row conductor and a column conductor (see figure). To "read" the contents of a memory cell — that is, to sense the resistance at an intersection, a potential of typically 5 V is applied across the intersection via the row and column conductors. This can be done, for example, by leaving the row conductor at ground potential and applying +5 V or −5 V to the column conductor, or vice versa.

Because neutral polypyrrole forms complexes spontaneously with TCNQ, the energy involved in the transition between conductor and insulator is very small. The transition is due to the migration of electrons between the polypyrrole and the TCNQ in response to the applied voltage. To "write" or "erase" the contents of a cell — that is, to change the resistance at an intersection — a potential twice that of the reading potential is applied; for example, by applying +5 V to the row conductor and −5 V to the column conductor. The opposite change of resistance — that is, the reverse of the previous "erasing" or "writing" operation — is effected by the application of the reverse of the writing voltages.

To begin fabrication, a parallel set of row or column conductors is laid down on an insulating substrate, possibly by electrodeposition. The conductors are preferably gold, platinum, glassy carbon, or other passive material. An electrochemical cell is prepared with a solution of pyrrole monomer in a solvent of acetonitrile with an electrolyte of tetrabutylammonium perchlorate. The substrate and conductors are inserted in the solution, and a positive voltage is applied to them with respect to another electrode in the solution. This causes the pyrrole to polymerize and deposit onto the

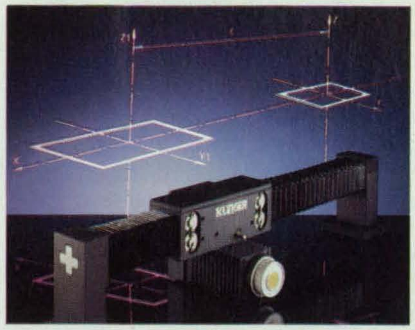
GV88 LONG TRAVEL LINEAR POSITIONER

Klinger Scientific Corporation's GV88 long travel linear positioning system is available in single axis X, XY or XYZ configurations. The system's modular design offers horizontal or vertical mounting, and a wide selection of standard options such as sway bars, counterweight assemblies, reinforced rails, or extended carriages. Step sizes are available in either English or metric units.

The system offers travel ranges from 10 to 60 inches in length, with resolutions from 0.0005 to 0.005 inches and speeds up to 20 inches/second. The GV88 provides cost effective solutions to complex problems encountered in automated production, non-contact inspection, non-destructive testing and a host of other technologies.

Prices start at $4,500.00. Delivery is 4-6 weeks after receipt of order.

For additional information, contact Klinger Scientific Corporation, 999 Stewart Avenue, Garden City, New York 11530. (516) 745-6800.



DC MOTOR DRIVEN MINI POSITIONER

Klinger Scientific Corporation has added its new and improved Miniature Motorized Linear Stage to its already impressive line of high-precision micropositioning equipment.

The new mini-stage features trajectory accuracy and high performance in a compact design. The DC motor and lead screw are internally mounted within the body of the stage, making this new device ideal for space limited applications. The mini-stage offers a 12 V DC motor drive to provide a travel range of 8mm with load carrying capacity to 10 lbs. and a maximum speed of 200 microns per second. An internally mounted optical encoder provides position feedback.

The modular design allows these stages to be mounted in X, XY or XYZ configurations, making this new device a cost-effective solution to a multitude of positioning problems in the fields of fiber optics, alignment and test, solid state laser systems, biomedical and OEM applications.

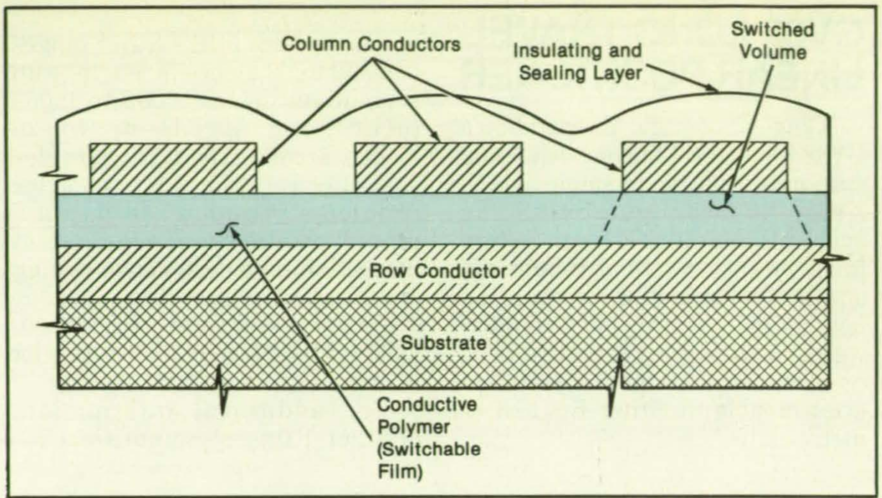
Delivery is four weeks after receipt of order. For additional information, contact Klinger Scientific Corp., 999 Stewart Avenue, Garden City, New York 11530. (516) 745-6800.

conductors and substrate.

The electrolyte gives rise to an undesirable negative doping. Therefore, after deposition, the polarity of the electrochemical cell must be reversed long enough to remove the dopant. Next, a lithium salt of TCNQ is added to a new batch of acetonitrile solvent and 0 to 0.1 V applied to the conductors to obtain the desired amount of doping with TCNQ. The greater the density of the TCNQ dopant, the lower the electrical resistance in the "on" state.

Preliminary tests reveal a change in the resistance of a memory cell from about $10^{12}\ \Omega$ in the "off" state to about $10^{7}\ \Omega$ in the "on" state — a factor of 10^{-5}. The high resistance of the "on" state is desirable because it enables the use of a high density of cells without excessive thermal dissipation. Complete changes of state have been accomplished with 100-ms pulses, and response times may eventually be reduced to a few milliseconds.

This work was done by Ganesan Nagasubramanian, Salvador DiStefano, and Jovan Moacanin of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 78 on the TSP Request Card.*



A **Thin Film of Conductive Polymer** separates a layer of row conductors from a layer of column conductors. The resistivity of the film at each intersection and, therefore, the resistance of the memory element defined by the row and column, can be increased or decreased by the application of a suitable switching voltage.

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

Edward Ansell
Director of Patents and Licensing
Mail Stop 301-6
California Institute of Technology
1201 East California Boulevard
Pasadena, CA 91125

Refer to NPO-17425, volume and number of this NASA Tech Briefs *issue, and the page number.*

Electrodes for Alkali-Metal Thermoelectric Converters

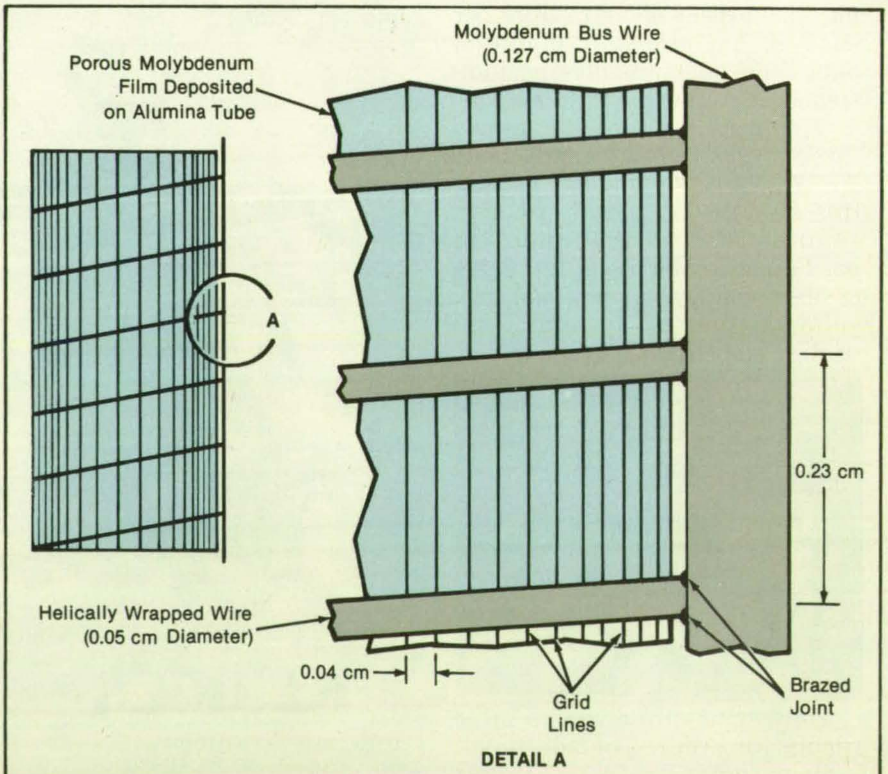
A new design decreases cell impedance.

NASA's Jet Propulsion Laboratory, Pasadena, California

The combination of a thin, porous electrode and an overlying collector grid reduces the internal resistance of an alkali-metal thermoelectric converter cell. Such converters could be used to transform solar, nuclear, and waste heat into electric power. The low resistance of the new electrode and grid boosts power density nearly to 1 W/cm^2 of electrode area at typical operating temperatures of 1,000 to 1,300 K.

Thin molybdenum electrodes with fine overlying current-collecting grids have been operated at stable power densities of 0.5 W/cm^2. Impedance analyses of these electrodes indicate that more substantial improvements, to about 0.6 to 0.7 W/cm^2, can be achieved with finer grids, as in the conceptual model described below. Power densities above 0.5 W/cm^2 would lead to alkali-metal thermoelectric-converter system efficiencies of 20 or more percent.

The porous molybdenum electrode film 0.2 to 0.5 μm thick is deposited on an alumina tube substrate. On the film are photolithographically-deposited parallel conductive strips, 0.004 cm wide and 0.04 cm apart (see figure). A wire 0.05 cm in diameter is wrapped around the tube in a helix of 0.23-cm pitch, in contact with the parallel strips. A longitudinal molybdenum wire 0.127 cm in diameter is brazed to the helical wires, thus providing an electrical bus



The **Conductive Grid Encircles** the electrode film on an alumina tube. A bus wire runs along the tube to collect electrical current from the grid.


TEAM WORK
ARIANE PUTS SATELLITES INTO SPACE THAT SPEAK 27 LANGUAGES. AS INDUSTRIAL ARCHITECT AEROSPATIALE COOPERATES WITH 11 EUROPEAN COUNTRIES PROVIDING SPACE-AGE TECHNOLOGY AND MANAGEMENT SKILLS. WITH THE NUMBER OF SATELLITES LAUNCHED FOR AMERICAN COMPANIES, WE PROVE OUR CAPABILITY OF WORKING TOGETHER. AND AEROSPATIALE HAS BUILT MORE THAN 40 TECHNICALLY DIVERSIFIED SATELLITES, MANY OF THEM WITH AMERICAN PARTNERS. WORKING AND CREATING TOGETHER KEEPS US UP THERE. MEET THE TEAM.
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AEROSPATIALE INC. 1101. 15TH STREET N.W WASHINGTON DC 20005
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for the grid formed by the strips and wires. At maximum power the molybdenum film electrode reduces the effective impedance to the flow of sodium ions from the former value of 0.5 ohm-cm^2 to the new value of 0.1 ohm-cm^2. The grid compensates for the higher electrical sheet resistance of the film, yielding a total effective impedance for the cell of only 0.4 to 0.6 ohm-cm^2. The cell resistance could be reduced even further by the use of a thinner electrode and finer grid elements, but the electrode assembly would then be more difficult to manufacture.

This work was done by Roger M. Williams, Bob L. Wheeler, Barbara Jeffries-Nakamura, James L. Lamb, C. Perry Bankston, and Terry Cole of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 4 on the TSP Request Card.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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Pasadena, CA 91125

Refer to NPO-17159, volume and number of this NASA Tech Briefs issue, and the page number.

Alternating-Gradient Photodetector for Far Infrared

The dark current would be decreased and the photocurrent increased.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed detector of photons of wavelengths in the range of 30 to 200 μm would be made of alternating layers of lightly and heavily negatively doped germanium. The layers would be formed in sequence by conventional chemical-vapor deposition. The alternating-gradient structure would enhance the collection of photogenerated charge carriers while suppressing the dark current, thus achieving high detectivity.

The heavily doped layers have an impurity band that narrows the extrinsic energy gap for response in the far-infrared range, while the lightly doped layers block dark current and support an electric field. In germanium, an optimum energy gap can be achieved only at moderately high doping, but vanishes at the still higher concentrations needed for good absorption of the far infrared photons. Therefore, it is necessary to increase the total thickness of the heavily doped layers to achieve good quantum efficiency. This is possible with the alternating gradient structure, where a pervasive electric field can be sustained across the alternating lightly-doped blocking layers. Charge carriers generated in a heavily doped layer would diffuse to an adjacent lightly doped layer where they would be accelerated for collection.

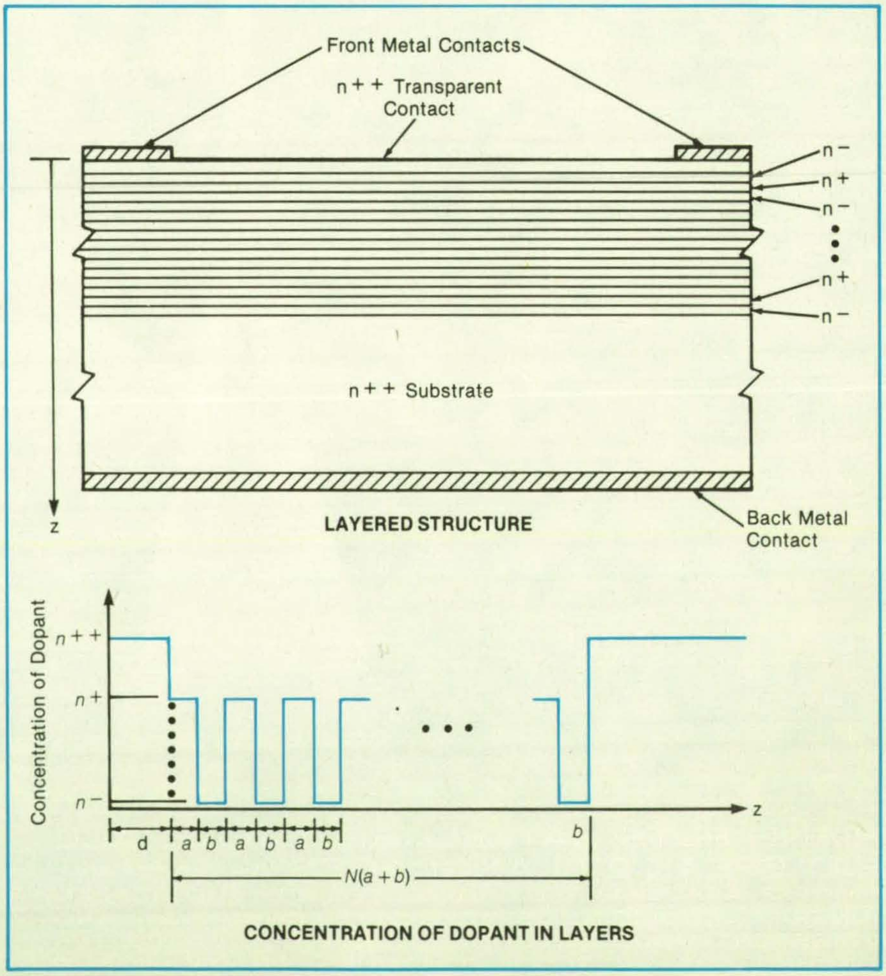
As shown in the figure, the detector would include a back metal contact, front metal contacts, and extra-heavily-doped germanium substrate and front-transparent-contact layers. The alternating structure in the middle would consist of N heavily-doped (n^+) germanium layers of thickness a and N lightly-doped (n^-) germanium layers of thickness b.

Assuming that most of the absorption takes place in the heavily doped layers, the total absorption thickness would be Na and should be at least as large as the photon-absorption length, or at least 100 μm. The thickness, a, of each n^+ layer must be small in comparison with the diffusion length for conduction electrons and may have an optimum value between 0.1 and 1.0 μm. The concentration, n^+, of dopant in the heavily doped layers would be about 3×10^{16} cm^{-3}. In the lightly doped layers, the concentration n^- would be about 10^{15} or less.

The voltage drop of about V/N in each lightly doped blocking layer could be used to control the level of impact ionization. The spectral response of the detector would depend on the concentration n^+ and could be tailored to specific applications. For example, n^+ could be varied from layer to layer or graded within each layer to obtain flat, broadband response.

This work was done by Albert W. Overhauser and Joseph Maserjian of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 150 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL *[see page 18]**. Refer to NPO-17235.*



Alternating Layers of n^+ and n^- germanium would provide high detectivity in the far-infrared spectral region. It should also be possible to make similar structures with positive doping and with such other semiconductors as silicon or gallium arsenide to obtain various spectral responses.

Hall-Effect Current Sensors for Integrated Circuits

Built-in devices would measure direct or alternating currents.

NASA's Jet Propulsion Laboratory, Pasadena, California

Microscopic Hall-effect sensors may eventually be built into integrated circuits to control and measure electrical currents. Preliminary design studies and experiments with macroscopic commercial Hall-effect sensors have been conducted to assess the feasibility, limitations, and need for further research and development of this concept. Potential applications include programmable power supplies and protective circuitry.

The basic principle of Hall-effect current sensing is well established. The Hall-effect sensor measures the magnetic field at a fixed position near a conductor, and the known proportionality (a function of geometry) between the magnetic field and the current in the conductor is used to infer the current. Although this basic principle is straightforward and fairly simple to apply in the case of large conductors carrying large currents and spaced far apart, several additional factors must be considered in miniaturization.

To concentrate the magnetic field sufficiently to obtain adequate sensor output, the conductor has to be constricted near the sensor, allowing the placement of the sensor close to the centerline (see figure). The length and width of the constriction and the configuration of the conductor at the approach to the constriction have to be chosen not only to accommodate the sensor but also to avoid excessive voltage drop, dissipation of power, and heating. In addition, the current density in the constriction must not be so high as to cause diffusion of the conductor atoms.

A two-sensor, differential scheme is preferred because it can reduce the sensitivity to the magnetic fields caused by currents in other conductors, which one is not seeking to measure. This, in turn, facilitates miniaturization by permitting the closer placement of conductors without excessive degradation of accuracy in the measurements. The differential scheme can also suppress even-order nonlinearities and thermal drifts in the individual sensors.

The maximum frequency at which accurate measurements can be made depends in part on the skin effect, which increasingly affects the distribution of current in the conductor as the frequency increases. An order-of-magnitude calculation shows that frequency distortion could be a significant issue in large sensors but not in monolithic sensors of currents of the order of 1 A. Other issues to be considered in development and design include the responses to transient currents and the need for electrostatic shielding to reduce capacitive coupling of transient voltages to the sensors.

This work was done by Wally E. Rippel of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 98 on the TSP Request Card.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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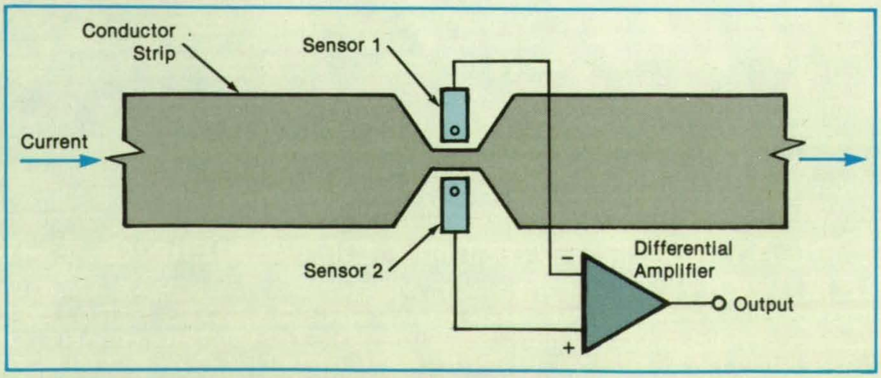
Refer to NPO-17476, volume and number of this NASA Tech Briefs *issue, and the page number.*

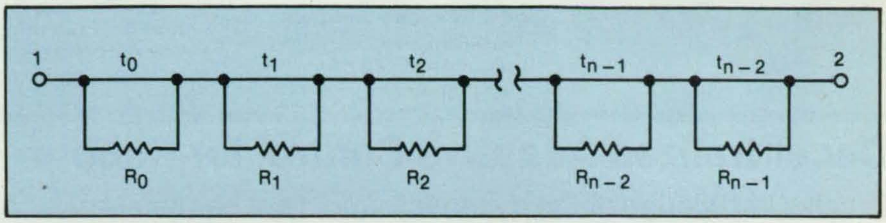


Hall-Effect Sensors are placed near a constriction in a conductor strip. The differential configuration reduces the effects of stray magnetic fields, nonlinearities, and changes in temperature.

N-Bit Binary Resistor

Binary resistors in series can be tailored to a precise value of resistance.

Langley Research Center, Hampton, Virginia



The **Desired Value of Resistance** is obtained by cutting the appropriate traces across the resistors.

A multibit, binary-based, adjustable resistor with high resolution can be used in many applications where precise resistance is required. The n-stage or n-bit resistor network design is shown in the figure. If each resistor has a resistance twice that of the one on its immediate left, then

$$R_1 = 2R_0,$$
$$R_2 = 2R_1 = 4R_0, \ldots,$$

and

$$R_{n-1} = 2R_{n-2} = (2^{n-1})R_0$$

The resistors $R_0, R_1, \ldots,$ and R_{n-1} are tied together by traces $t_0, t_1, \ldots,$ and t_{n-1}. In the "uncut" form shown in the figure, the total resistance between points 1 and 2 approaches 0; that is, $R = 0$. If trace t_0 is cut or removed, then $R = R_0$. In similar fashion, if t_1 is removed, then $R = R_1$. If t_0 and t_1 are both removed, then $R = R_0 + R_1 = 3R_0$. Since the resistances are binary based, any resistance value between 0 and $(2^n - 1)R_0$ can be achieved by removing the appropriate traces. For example, in a 10-bit network, to make $R = 613R_0$, traces t_0, t_2, t_5, t_6, and t_9 are removed to yield

$$R = (2^9 + 2^6 + 2^5 + 2^2 + 2^0)R_0 = (512 + 64 + 32 + 4 + 1)R_0 = 613\,R_0$$

The configuration of this type of network is not limited to the form shown. For example, to minimize the overall physical size, a circular configuration might be preferable. This resistor network can be deposited on a bondable foil. A 10-bit foil resistor network that has a full-scale resistance on the order of 1 ohm can be manufactured on a ¼- by ⅛-in. (6.35- by 3.2-mm) foil by existing techniques. Larger full-scale resistance networks also can be readily accommodated by use of this concept.

This work was done by Ping Tcheng of **Langley Research Center**. *No further documentation is available.*
LAR-13709

Electronic Systems

Decentralized Adaptive Control for Robots

Precise knowledge of the dynamics would not be required.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed scheme for the control of a multijointed robotic manipulator calls for an independent control subsystem for each joint, consisting of a proportional/integral/derivative feedback controller and a position/velocity/acceleration feedforward controller, both with adjustable gains. The independent joint controllers would compensate for unpredictable effects (e.g., friction, variations in payload, and imprecise knowledge of the dynamics of the manipulator), gravitation, and dynamic coupling between motions of joints, while forcing the joints to track reference trajectories. The scheme is amenable to parallel processing in a distributed computing system wherein each joint would be controlled by a relatively simple algorithm on a dedicated (to read "torques") microprocessor.

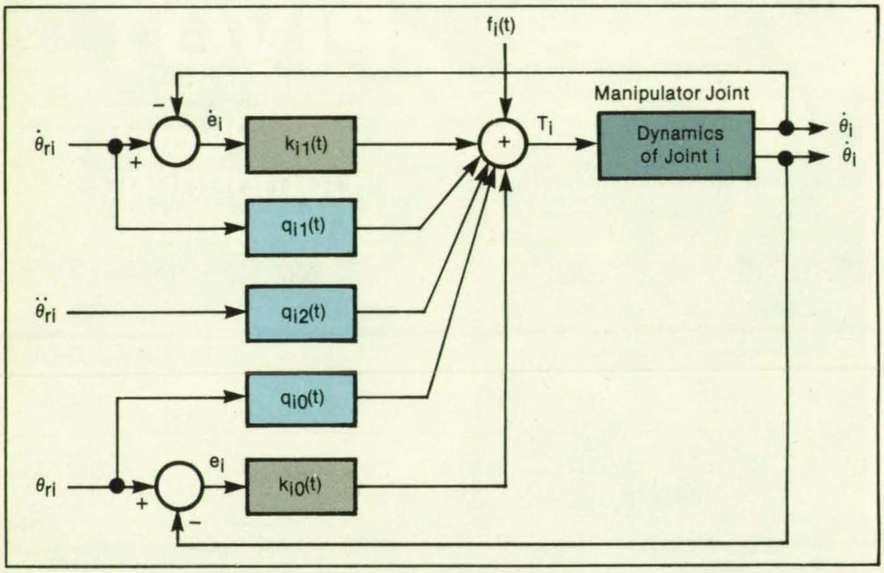


Figure 1. The **Adaptive Independent Controller** of joint i would generate the torque T_i that would make the actual trajectory $(\theta_i, \dot{\theta}_i, \ddot{\theta}_i)$ of this joint track the reference trajectory $(\theta_{ri}, \dot{\theta}_{ri}, \ddot{\theta}_{ri})$. The k terms represent adjustable feedback gains; the q terms, adjustable feedforward gains. These gains would be adjusted according to the adaptation law.

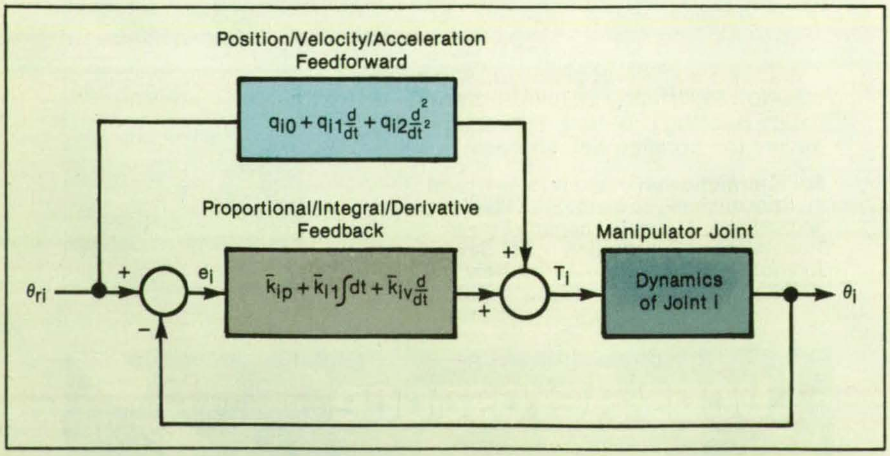


Figure 2. The **Controller of Figure 1,** with appropriate adaptive gains, can be represented as the combination of a position/velocity/acceleration feedforward controller and a proportional/integral/derivative feedback controller.

For the purpose of the scheme, it is convenient to view each joint as a subsystem of the entire manipulator system. The subsystems are considered to be interconnected by disturbance torques that represent the inertial coupling, Coriolis, centrifugal, frictional, and gravitational effects. The problem is to design the set of independent joint controllers in which the ith controller generates the joint torque $T_i(t)$ (where t = time) by responding only to the actual joint-angle trajectory $\theta_i(t)$ and the reference joint-angle trajectory $\theta_{ri}(t)$ and makes $\theta_i(t)$ track $\theta_{ri}(t)$. The adaptive independent controller dedicated to the ith joint would be described by

$$T_i(t) = f_i(t) + [k_{i0}(t)e_i(t) + k_{i1}(t)\dot{e}_i(t)] + [q_{i0}(t)\theta_{ri}(t) + q_{i1}(t)\dot{\theta}_{ri}(t) + q_{i2}(t)\ddot{\theta}_{ri}(t)]$$

as shown in Figure 1, where $e_i(t) = \theta_{ri}(t) - \theta_i(t)$ is the position-tracking error of joint i. The term $f_i(t)$ represents an auxiliary signal synthesized by the adaptation scheme to improve the tracking performance and partly compensate for the disturbance torques. The term in the first set of brackets represents the adaptive position/velocity feedback controller with the adjustable gains $k_{i0}(t)$ and $k_{i1}(t)$ acting on the position and velocity tracking errors $e_i(t)$ and $\dot{e}_i(t)$, respectively. The term in the second set of brackets represents the adaptive position/velocity/acceleration feedforward controller with the adjustable gains $q_{i0}(t)$, $q_{i1}(t)$, and $q_{i2}(t)$ operating on the desired position $\theta_{ri}(t)$, velocity $\dot{\theta}_{ri}(t)$, and acceleration $\ddot{\theta}_{ri}(t)$, respectively.

A theorem derived via the theory of model-reference adaptive control provides the necessary controller-adaptation law in the form of specifications for the auxiliary signal, feedback gain and feedforward gain. The resulting independent-joint-control law can be expressed as that of the

combination of the proportional/integral/derivative feedback controller and the proportional/derivative/second-derivative feedforward controller illustrated in Figure 2.

The controller-adaptation laws are simple and involve only a few arithmetic operations. The proportional-plus-integral adaptation laws give a large family of adaptation schemes, from which the most suitable scheme for a particular application can be selected. The use of proportional-plus-integral adaptation laws yields improved convergence and increased flexibility in comparison to the conventional integral adaptation laws.

This work was done by Homayoun Seraji of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 16 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA's Resident Office-JPL [see page 18]. Refer to NPO-17542

Digital Integrate-and-Dump Filter With Offset Sampling

Detection of weak signals would be improved slightly.

NASA's Jet Propulsion Laboratory, Pasadena, California

A digital integrate-and-dump filter has been proposed for the detection of weak rectangular-pulse signals corrupted by additive white Gaussian noise. The theory of the filter takes account of the degradation of performance caused by offset sampling, in which the beginning and/or end of the sampling period differs from the desired starting and/or stopping time, respectively, of the integration.

An ideal, perfectly-synchronized integrate-and-dump filter (IDF) is the optimum matched filter for coherent detection of rectangular-pulse signals corrupted by additive white Gaussian noise (AWGN). In practice, digital implementation of the IDF has several advantages over its analog counterpart, including the following:

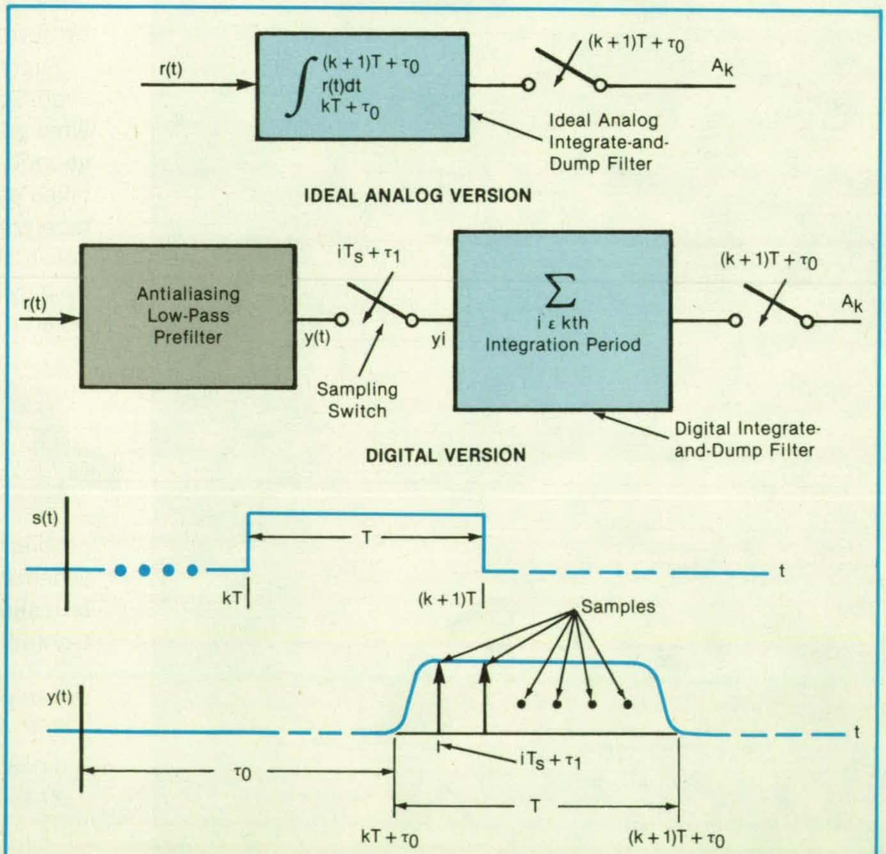
- Ability to dump instantaneously with no overshoot,
- Absence of drift from the quiescent operating point, and
- The use of advanced digital integrated circuits to perform multiplication and accumulation with greater accuracy.

To prevent aliasing in the digital implementation, the input signal must be low-pass-filtered prior to sampling. This prefiltering degrades the performance of the receiver by causing intersymbol interference and limiting the bandwidth. The additional degradation of performance caused by offset sampling is negligible when the number of samples per symbol is large but becomes significant when that number is small. The performance of the digital implementation is evaluated as a function of the bandwidth, sampling frequency, and offset by comparison with the performance of an ideal, perfectly-synchronized analog implementation (see figure). (In the limit as the bandwidth of the prefilter and, consequently, the sampling rate approach infinity, the performance of the digital IDF converges to that of the ideal analog IDF.)

For the analysis, it is assumed that the sampling clock runs freely in the sense that it is not locked in phase to the symbol clock (thus allowing offset). Nevertheless, for most cases, perfect synchronization of symbols is assumed in the sense that the sampling frequency is an integral multiple of the symbol frequency and the receiver has perfect knowledge of the beginning and ending times of each symbol period. Quantization noise in the sampler and instability of the sampling clock are neglected.

The performances of digital and ideal analog IDF's were studied theoretically and with the help of Monte Carlo simulations. It was found that the digital IDF performs within 0.6 dB of the ideal analog IDF whenever the bandwidth of the prefilter exceeds four times the symbol rate and sampling is at the Nyquist rate (twice the bandwidth of the filter). If the sampling rate is increased to twice the Nyquist rate, the loss of performance can be reduced to 0.3 dB, of which 0.2 dB result from finite bandwidth and 0.1 dB from the digital IDF.

This work was done by R. Sadr and W. J. Hurd of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 72 on the TSP Request Card.*
NPO-17437



NOTES:

1. τ_0 = Time of propagation from transmitter to receiver.
2. T = Symbol period.
3. T_s = Sampling period.
4. τ_1 = Sampling offset.
5. r(t) = Received signal modulation
6. s(t) = Transmitted signal modulation.
7. y(t) = Prefiltered signal modulation.
8. t = Time.
9. i and k are integers.
10. A_k = the sampled output of either integrate-and-dump filter from the kth integration period.

The **Performances of Integrate-and-Dump Filters** are analyzed by comparison of the digital and the ideal analog versions. Transmitted and noiseless prefiltered waveforms are shown to illustrate time relationships.

Pulse Vector-Excitation Speech Encoder

The number of computations would be reduced substantially.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed pulse vector-excitation speech encoder (PVXC) would encode analog speech signals into a digital representation for transmission or storage at rates below 5 kilobits per second. PVXC would produce a high quality of reconstructed speech, but with much less computation than is required by comparable speech-encoding systems. PVXC has some of the characteristics of multipulse linear predictive coding (MPLPC) and of code-excited linear prediction (CELP).

In the encoder (see figure) the input speech is converted from sequences of 40 samples to 40-dimensional vectors $\boldsymbol{s}_n$, with 4 vectors constituting a frame. Each $\boldsymbol{s}_n$ is preprocessed by passage through a perceptual-weighting filter $W(z)$ followed by subtraction of the deterministic speach component (synthesis filter zero input response) from $\boldsymbol{r}_n$ to generate the random speech component $\boldsymbol{z}_n$. Meanwhile, a set of N pulse-like code vectors, $\boldsymbol{c}_j$, weighted by gains G_j is passed through a long-term LPC-synthesis filter $H_\ell(z)$ and a short-term weighted LPC-synthesis filter $\tilde{H}_s(z) = H_s(z)W(z)$ to produce a set of N weighted candidate synthetic-speech vectors $\boldsymbol{z}_j$.

The variable gain G_j is selected to minimize the mean-square error between $\boldsymbol{z}_j$ and $\boldsymbol{z}_n$. The perceptual-weighting filter $W(z)$ shapes the spectrum of the error signal to make it similar to that of $\boldsymbol{s}_n$, thereby masking some of the distortion that would otherwise be perceived by the listener.

An exhaustive search is performed to find the excitation vector, $\boldsymbol{c}_j$, that minimizes the Euclidean distortion $\|\tilde{e}_j\|^2$ (where $\tilde{e}_j$ is the error vector) between $\boldsymbol{z}_n$ and $\boldsymbol{z}_j$. Once the optimal c_j is selected, an excitation index ("code-book" index) that identifies it is transmitted to the remote station, together with the associated gain. In addition, the parameters of $H_\ell(z)$ and $\tilde{H}_s(z)$ are transmitted once per input speech frame (after every fourth $\boldsymbol{s}_n$).

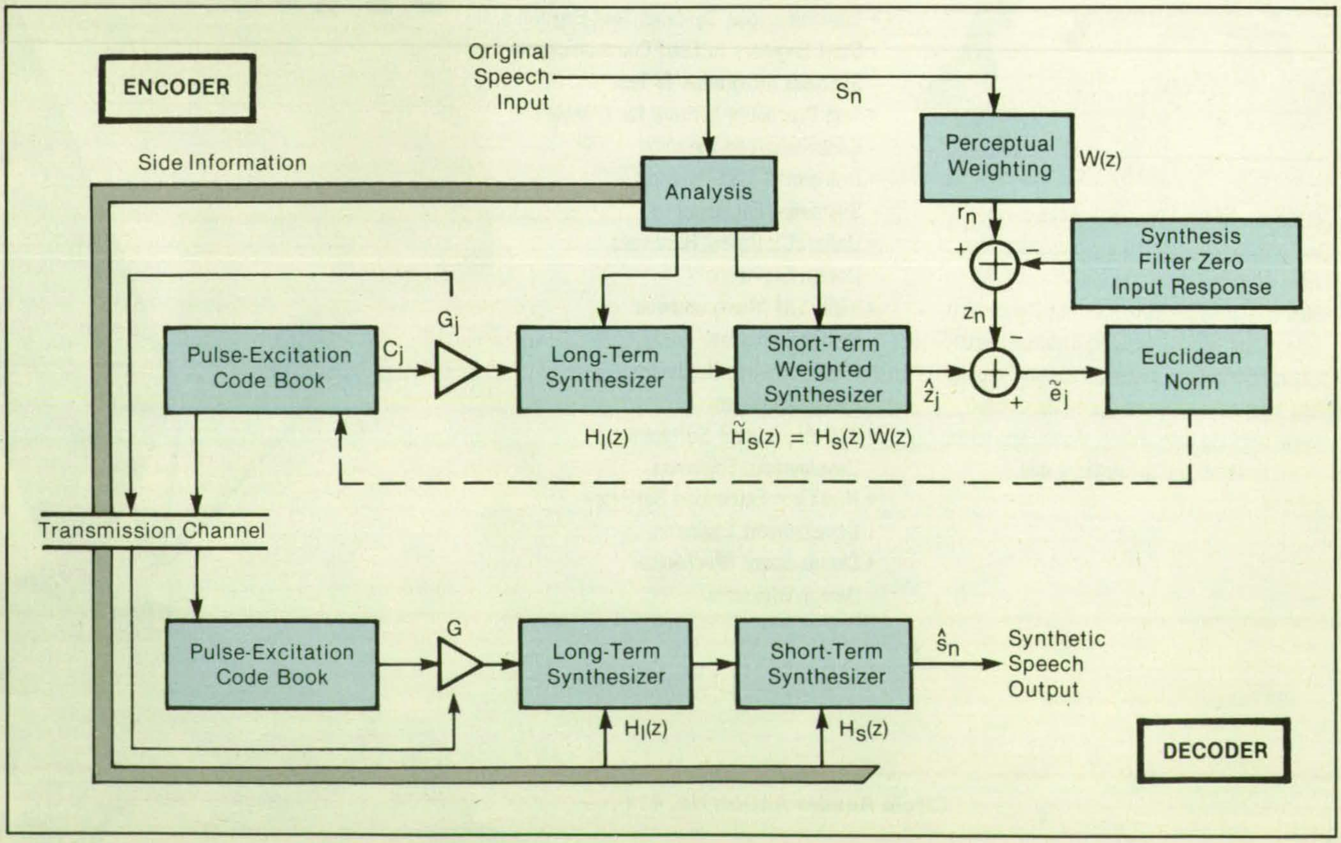
The complexity of the search through the "code book" is reduced by the use of the random speech component $\boldsymbol{z}_n$. The elimination of the deterministic component enables the initial memory values in $\tilde{H}_s(z)$ and $H_\ell(z)$ to be set to zero when synthesizing the $\boldsymbol{z}_j$ vectors, without affecting the choice of the optimal $\boldsymbol{c}_j$. Once the optimal code vector is determined, the filter memory from the previous vector can be updated for use in encoding the subsequent vector. This filter representation reduces the amount of computation further by expressing the speech-synthesis operation efficiently as a matrix-vector product and leads to a centroid calculation for use in the design of optimal "code books." The selection of an optimal code vector in PVXC should require 0.67 million multiplications and additions per second — much fewer than the 440 million required in CELP.

This work was done by Grant Davidson and Allen Gersho of the University of California for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 113 on the TSP Request Card.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for the commercial use of this invention should be addressed to

The Regents of the University of California
c/o Office of Research Administration
University of California
Santa Barbara, CA 93106

Refer to NPO-17131, volume and number of this NASA Tech Briefs *issue, and page number.*



The **Vector-Excitation Speech-Encoding System** uses a mathematical model of the vocal tract in conjunction with a set of excitation vectors and a perceptually-based error criterion to synthesize natural-sounding speech.

Computational Architecture for Control of Remote Manipulator

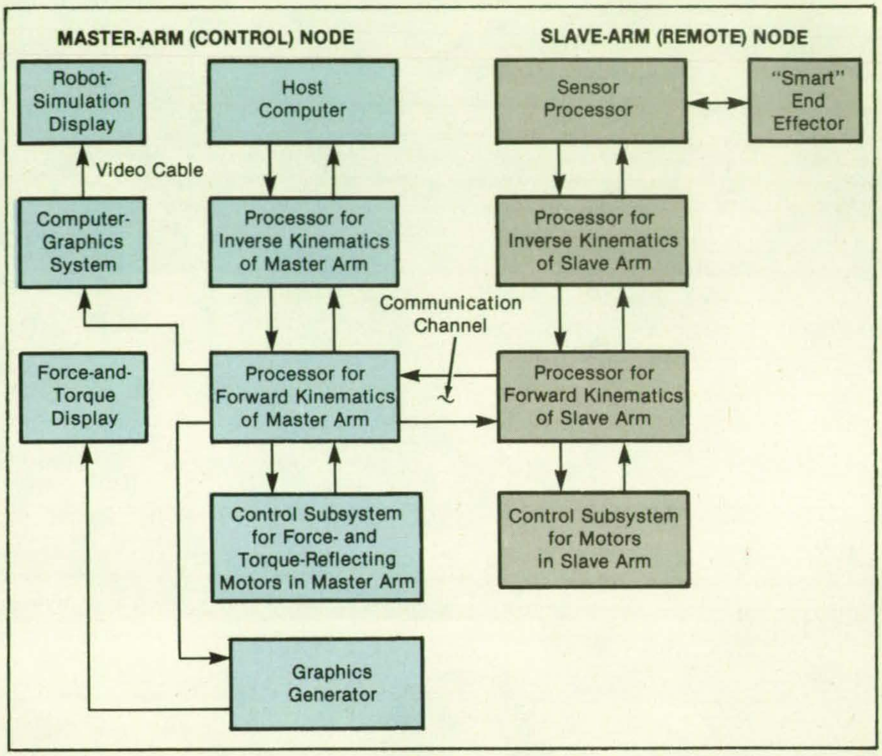
Synchronization is done by hardware to reduce the software overhead.

NASA's Jet Propulsion Laboratory, Pasadena, California

A computational architecture is guiding the development of a distributed computing system for the bilateral control of a robotic remote manipulator. Bilateral control involves master and slave arms. Information from sensors on the slave arm is used to back-drive the master arm to give the human operator a sense of force and/or torque. The kinematic and dynamic relationships between the two arms are established by the mathematical transformations computed by the processors. Because the two arms can be separated by a large distance, it is necessary to have two computing nodes: one at the master-arm site in the control station and another at the remote slave-arm site (see figure).

Such distributed computation requires a tightly integrated computational architecture within each computing node and between the two nodes. For this reason, a multibus computing architecture was selected. Multiple bus masters operating in a closely coupled environment enable sharing of information from various sources within a processing node. The ability to share memory space makes it easy to synchronize multiple processors to coordinate control of the telerobot and associated handling of sensor data in real time.

The principal method embodied in the architecture is the use of fully synchronized, interruption-driven software. Inasmuch as one of the objectives of this development is to use data-processing resources efficiently, synchronization is done by the equipment to reduce the sizes of computer programs. The architecture also balances the load on the communication channel that connects the two nodes.



Computing Resources are located at both the master-arm node (control station) and the slave-arm node (remote station). This architecture provides for effective control while reducing the computational burden on the host computer and reducing and balancing the load on the communication channel.

This work was done by Zoltan F. Szakaly of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 13 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA's Resident Office-JPL [see page 18]. Refer to NPO-17401

Robotic Target-Tracking Subsystem

The position and orientation of the target are measured in six degrees of freedom.

John F. Kennedy Space Center, Florida

A robotic vision subsystem measures the relative position and orientation of a specially designed target. The subsystem uses standard image-processing algorithms implemented directly in circuitry instead of computer programs, which consume more time. This feature makes it possible to extract complete sets of target-tracking data from successive image frames at the rate of 30 frames per second. The subsystem could be useful in industrial assembly operations that require automatic joining of parts that are initially oriented and moving randomly.

A solid-state video camera views the target, which consists of five bright or reflective circles, four of which are located at the corners of a square and the fifth of which is located at the center of the square but offset from the plane of the square (see figure). The raw image data are sent to the image-processing circuitry, which performs a convolution difference-of-Gaussian edge-analysis filtering operation to bring out the picture elements that represent the edges of the circles.

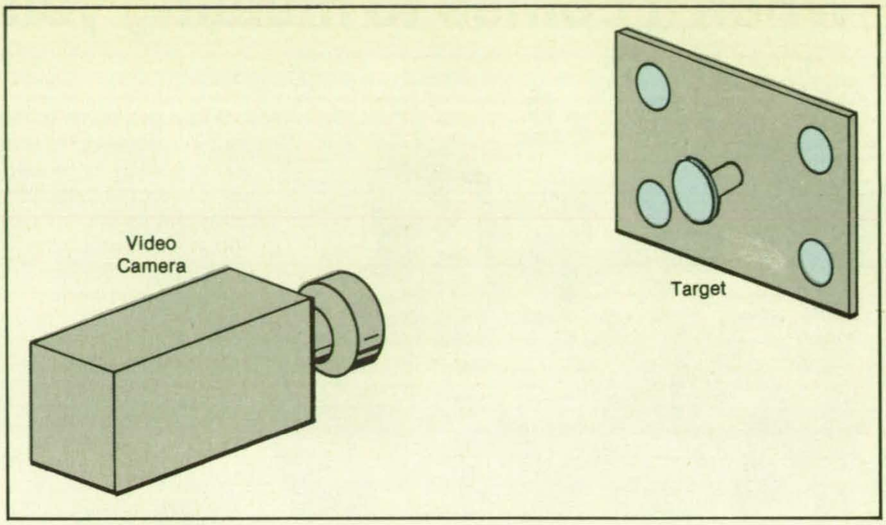
The image data are then processed further to obtain the centroids of the five circles. The locations of these centroids relative to each other and to the overall image frame are processed to obtain three Cartesian coordinates of the target relative to those of the camera. Triangulation calculations based on the vector relationships among the locations of the five circles and the central axis of the target yield the roll, pitch, and yaw angles that describe the orientation of the target relative to the line of sight and the field of view of the camera. Thus, the relative position and orientation of the target are determined in all six degrees of freedom. The offset of the central

circle from the plane of the other four circles can be increased or decreased to increase or decrease the sensitivity of the subsystem to the pitch and yaw of the target.

The output data may have to be transformed into spherical or other coordinates used by the robot. However, this transformation can be performed easily in software. If the robot is changed, it is necessary only to change this software.

This work was done by Lawrence M. Shawaga of **Kennedy Space Center**. *For further information, Circle 32 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Kennedy Space Center [see page 18]. Refer to KSC-11447



The **Five Bright Circles** of the target are positioned in such a way that the video images of them can be processed into data on the position and orientation of the target relative to the camera.

Improving Estimates of Phase Parameters When Amplitude Fluctuates

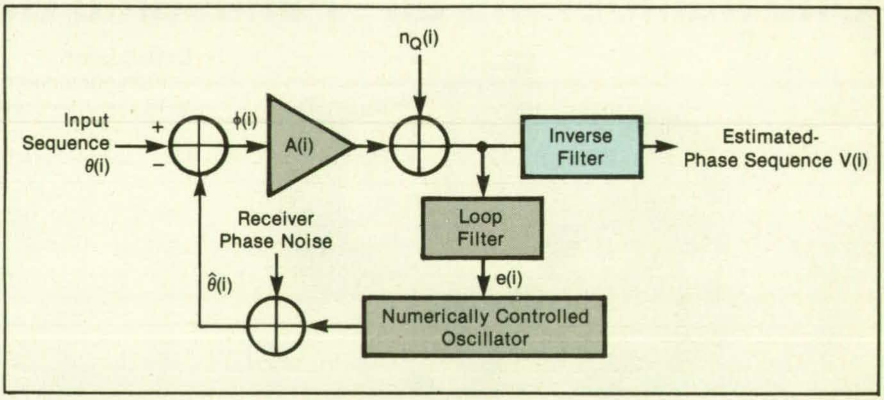
An adaptive inverse filter is applied to the incoming signal and noise.

NASA's Jet Propulsion Laboratory, Pasadena, California

A time-varying inverse-filtering technique has been developed to improve the digital estimate of the phase (and the parameters of the power spectral density of the phase) of a received carrier signal. More specifically, the technique is intended for use where the received signal fluctuates in amplitude as well as in phase and the signal is tracked by a digital phase-locked loop that keeps its phase error much smaller than 1 radian; that is, the loop remains in lock. The technique could be useful in navigation systems, the reception of time- and frequency-standard signals, and possibly spread-spectrum communication systems.

The technique is based in part on the observation that random variations in the transfer function of a conventional tracking loop can be attributed directly to the fluctuations in the amplitude of the signal. This suggests the use of a time-varying inverse filter to remove the unwanted effects of amplitude from the output of the phase detector. The necessary estimates of amplitude can be obtained from the in-phase samples, provided that the loop remains in lock as assumed.

The figure illustrates the linear mathematical model of the loop that applies as long as it remains in lock. The loop generates estimates $\hat{\theta}(i)$ of the received phase at sampling intervals i from the received phase sequence $\theta(i)$. The instantaneous phase error $\phi(i) = \theta(i) - \hat{\theta}(i)$ is multiplied by a relatively-slowly-varying sequence $A(i)$ that represents the fluctuating amplitude. With the addition of the equivalent noise sequence $n_Q(i)$, the output $y(i)$ of the phase detector becomes a sequence containing products and sums involving the amplitude, phase, noise, and the transfer functions of the loop filter and the numerically controlled oscillator.



The **Inverse-Filter** compensates for the fluctuations in the amplitude $A(i)$. The output of the inverse filter is an estimate of the phase of the received signal, plus a modified noise component.

The inverse-filtering equations apply a correction to $y(i)$ based on the estimate $\hat{A}(i)$ of the amplitude sequence $A(i)$. The effect of the filter can be expressed as a recursion on the sequence $y(i)$. The output of the inverse filter is a sequence

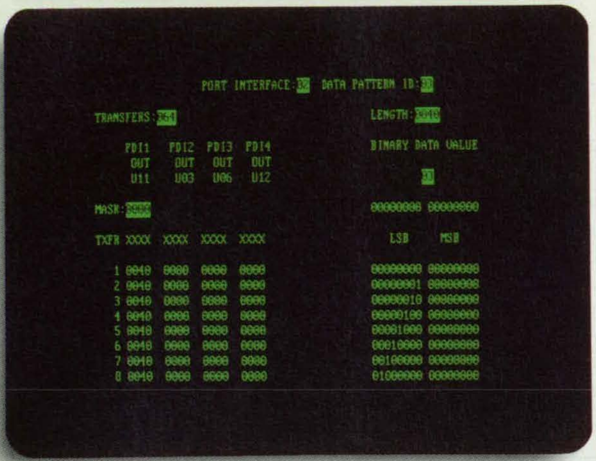
$$v(i) = \xi(i) + [n_Q(i)/\hat{A}(i)]$$

where $\xi(i)$ is the estimate of the total phase of the received signal (including the components due to instability in the transmitter oscillator, Doppler shift, and other effects of propagation).

The inverse-filtered noise component is white noise. The power spectral density of the output signal contains the power-law or other spectral contribution of the received signal, which can be estimated by means of standard techniques.

This work was done by V. A. Vilnrotter, D. H. Brown, and W. J. Hurd of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 45 on the TSP Request Card.*
NPO-17560

TWO MONTHS.



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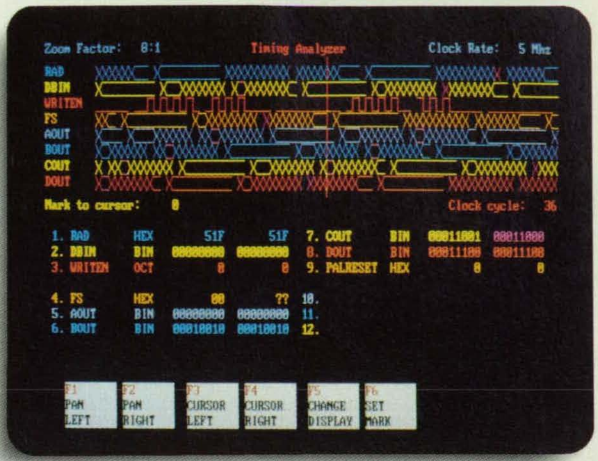

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Scanning Photoelectron-Emission Inspection Equipment

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Marshall Space Flight Center, Alabama

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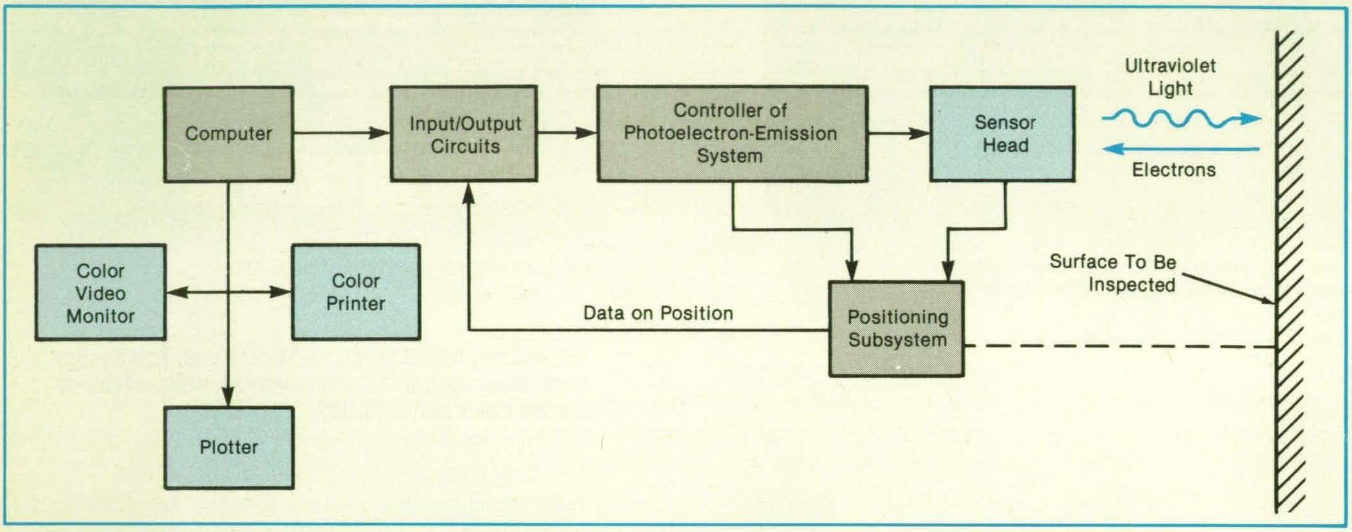
The equipment (see figure) includes a commercial photoelectron-emission sensor. The inspected surface is irradiated with ultraviolet photons from a source in the sensor head while an anode in the sen-



The **Photoelectron-Emission Sensor** is held at a fixed distance from the surface to be inspected and scanned across the surface. Data on photoemission as a function of position on the surface are used to generate a map of contamination of the surface.

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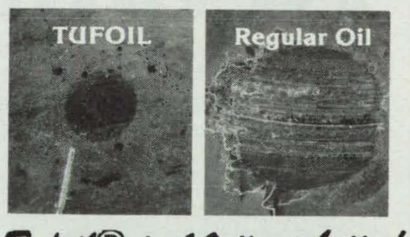

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sor head collects photoelectrons ejected from the surface by absorbed photons. If the intensity and spectrum of the ultraviolet light and the distance between the sensor and the surface are held constant, then the photocurrent (typically 10^{-12} to 10^{-10} A) varies according to the amount and type of contamination. For example, a clean surface usually acts as a source of photoelectrons, and a non-photo-emitting contaminant causes a decrease in the photocurrent. On the other hand, a photoemitting contaminant could cause an increase or decrease in current, depending partly on its thickness.

The sensor head is mounted on a servo-controlled positioning mechanism to maintain the correct distance to the inspected surface. The sensor can be scanned across the surface (or, alternatively, the surface moved past the sensor) by any suitable combination of translation and rotation stages. Data on the inspected position are taken from shaft-angle or other encoders in the scanning mechanism(s) and recorded with photoemission-measurement data. These two streams of data are processed into a false-color or other map of contamination, which can be displayed on a color video monitor, plotted, or printed.

Measurements of photoemission can be calibrated by correlation with the strengths of bonds made to standard specimens known to be contaminated to various degrees. This calibration becomes the basis for acceptance or rejection of parts of that type. If, for example, the map of a surface includes areas where the photoemission indicates contamination above the allowable level, those areas can be cleaned and reinspected until the map shows the entire surface to be sufficiently clean.

This work was done by Raymond L. Gause of **Marshall Space Flight Center**. *For further information, Circle 19 on the TSP Request Card. MFS-27203*

Force-Feedback Cursor Control

A robot controller would move a cursor and manipulate images.

NASA's Jet Propulsion Laboratory, Pasadena, California

The use of force-feedback hand-held controllers has been proposed to help computer operators position cursors on computer video displays. Such controllers were originally developed for controlling remote manipulators on robots: they transmit users' hand and finger movements to the manipulators and feed back, to the users' hands, forces that represent the interactions of the manipulators with the manipulated objects.

To control a cursor, a hand controller would replace a joystick or electronic mouse. As with a joystick or mouse, motion of the handlelike controller in a plane would move the cursor horizontally and vertically on the screen. The operator would press a button on the handle to obtain the action when the cursor reaches the desired position indicated by an icon or image.

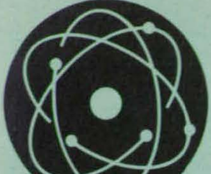
Unlike a joystick or mouse, the controller would have additional degrees of freedom. Thus, icons on the screen could be made to respond to movement toward or away from the screen and to rotations. If, for example, a picture of a switch were oriented vertically on the screen, the operator might open or close the switch by rotation of the controller around the pitch axis. In another possible variation, an image of a control knob might be rotated by movement around the roll axis. With many such images on the screen, the operator would use the controller to move the cursor to the proper image, then press a button to activate the function represented by the image.

With special software, the force-feedback ability of the controller could be brought into play. Force feedback could repel the controller and cursor from the boundaries of images and attract them toward the centers, preventing the cursor from being set in ambiguous positions. Force feedback could also guide the operator's hand in following straight lines and even along curves.

Once the cursor is positioned on the image of a switch, the controller could produce a force that the operator must overcome to change the position of the switch. The force adds realism by simulating the breakaway force of a real toggle switch and thereby reduces the likelihood of false operation.

Force feedback could also transmit information to alert the operator to conditions not necessarily related to images on the screen. For example, a vibrating force could signal an alarm that requires immediate attention. Because humans respond faster to tactile stimuli than to visual ones, force feedback can speed corrections.

This work was done by Blake Hannaford and Zoltan F. Szakaly of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 21 on the TSP Request Card.*
NPO-17520



All-Optical Photochromic Spatial Light Modulators

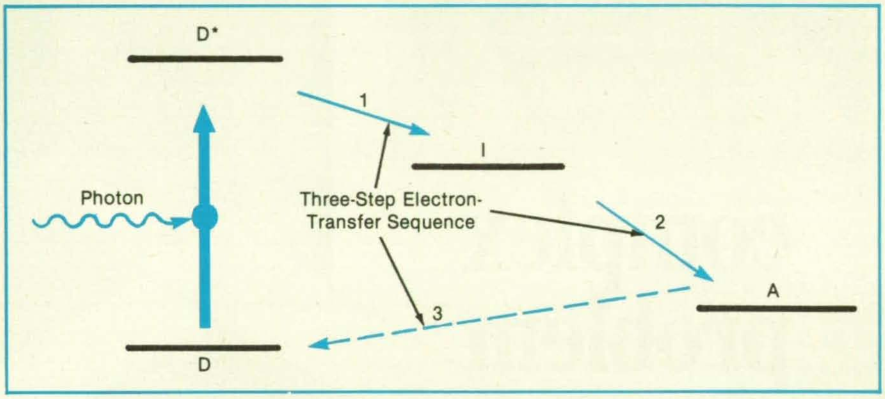
Photochemical transfer of electrons would enable fast reading and writing.

NASA's Jet Propulsion Laboratory, Pasadena, California

A concept for all-optical spatial light modulators holds promise for highly parallel, fast optical computing — for example, in the enhancement or recognition of images. Such a modulator would be a single piece of photochromic material in which information would be written, or from which information would be read, by beams of light. Devices of the new type might operate as two-dimensional transmission or reflection masks, three-dimensional holograms, incoherent-to-coherent image converters, or wavelength converters over the spectral range from ultraviolet to near infrared.

The new concept is based on the transfer of electrons between donor and acceptor molecules (chromophores) randomly distributed or covalently linked and dispersed in a glassy-polymer host material. This transfer would cause significant changes in the optical-transmission characteristics of the material and could, therefore, be used to modulate the transmission of a reading beam of light impinging on the material.

The writing beam of light used to induce the transfer of charge would be scanned across the device or used to project an image onto it, thus optically forming a mask of spatially varying transmission — that is, spatial modulation. Because the transfer of charge would take place over typical molecular distances of about 100 Å or less, the inherent spatial resolution of the device would be limited only by the diffraction of light, which is characterized by much greater lengths.



This is the **Simplest of Three-Species Charge-Transport Pathways.** Initially, a photon raises a donor molecule D to an excited state. An electron is transferred from D to an intermediate molecule I, then to a preferably-more-distant acceptor molecule, A, faster than direct D^+I^- recombination can occur. Finally, the only way that recombination can occur is by quantum-mechanical tunneling of the electron along the full distance from A^- back to D^+.

The electron-transfer/photochromic concept involves the use of a three-state intermolecular charge-tunneling scheme like that of photosynthesis (see figure) to make possible a switched state. The charge-separation and recombination rates would be tunable over several orders of magnitude, making the devices useful for a variety of computing strategies. The charge-separated state would appear rapidly, within picoseconds to microseconds. Because the charge-transport switching events would involve no breakage or formation of chemical bonds, the device could be subjected to many reading and writing cycles.

Rough estimates of characteristics of the proposed spatial light modulators combine the best characteristics from existing Pockels cells, volume holograms, photorefractive materials, and liquid crystals. In addition to the short response times and high resolutions mentioned above, these include sensitivities of the order of 10–100 $\mu J/(cm)^2$.

This work was done by David N. Beratan and Joseph W. Perry of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 54 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA's Resident Office-JPL [see page 18]. Refer to NPO-17612

Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

Very-Long-Baseline Interferometry Using Cheap Satellites

Celestial radiation below 25 MHz, heretofore inaccessible, could yield new insights.

A report discusses the feasibility of an array of small satellites that would be deployed in a high orbit around the Earth to monitor celestial radio sources at frequencies less than 25 MHz. The objective is to make a high-angular-resolution map of such sources over the entire sky by use of very-long-baseline interferometry (VLBI). At present, this part of the celestial radio spectrum is essentially unexplored because it is hidden from terrestrial antennas by the ionosphere most of the time and subject to interference by terrestrial sources.

The satellites would be built cheaply in "get-away-special" canisters ("GAS cans") similar to those developed for carrying small experiments aboard the Space Shuttle. (Alternative launching craft would have to be used, however, because the Space Shuttle cannot deploy such canisters in

sufficiently high orbits.) Because the multiple-satellite array would be an aperture-synthesis array of many elements, it would have inherent protective redundancy. Thus, the success of the project would not be threatened by the failure of a few satellites. This feature would relax the requirements for long-term reliability, thereby helping to keep the cost low.

The main technical discussion is contained in nine chapters. Chapter I introduces the concept of the VLBI mission and describes the 2-day workshop-type conference at which the subjects of the other chapters were discussed. Chapter II describes the scientific motivation, including a list of questions regarding the radio spectrum that might be answered by data from the VLBI array.

Chapter III discusses technical requirements and problems involved in observation at various frequencies. Topics include the ionospheric critical frequency, interstellar and interplanetary scattering, radiation from auroras, the range of angular sizes of sources, and the large number of detectable sources. There is also a brief discussion of the cost.

Chapter IV describes the "GAS-can" concept and the standard configuration of an emerging series of small, inexpensive satellites designed to be launched in improved "GAS cans". Chapter V presents some of the engineering considerations. These include engineering tradeoffs that depend on the altitude of the orbit, the inclination of the orbit, alternative launching vehicles and organizations, the number of elements in the array, and keeping track of the changing relative positions of elements in the array.

Chapter VI describes some of the radio equipment likely to be carried aboard the satellite, including various kinds of antennas and receiving electronics. Chapter VII discusses the requirements for telemetry and ground support equipment. Chapter VIII outlines topics that would have to be studied further to arrive at a satisfactory design. Chapter IX presents some additional topics to be studied and some conclusions, the major one of which is that there appears to be no insurmountable obstacle to the deployment of the multiple-satellite VLBI array.

Following Chapter IX is a brief list of references. There are also three appendixes: one on vibrations and stability of a satellite, one on the application of magnetic torquers, and one on the separation of coorbiting satellites that is caused by differences in atmospheric drag.

This work was done by M. J. Mahoney, D. L. Jones, T. B. H. Kuiper, and R. A. Preston of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Low Frequency VLBI in Space Using 'GAS-Can' Satellites," Circle 133 on the TSP Request Card. NPO-17488*

Gravitation- and Conduction-Driven Melting in a Sphere

Simplifying assumptions lead to an approximate closed-form solution.

A theoretical paper discusses the melting of a solid sphere in a spherical container. It develops a mathematical model of the melting process, based in part on simplifying assumptions like those used in the theories of lubrication and film condensation. The resulting equation for the melting speed as a function of the melting distance can be solved approximately in closed form.

The mathematical model starts with the following conditions and assumptions: The solid sphere is initially at the melting temperature. The temperature of the wall is suddenly raised to a higher constant value. The solid begins to melt inward and is denser than the liquid, so it starts to move downward. The downward motion is accompanied by the generation of liquid at the melting interface, and the liquid is pushed up through a thin layer to the space above the solid. The melting at the top of the sphere is negligible.

The motion of the liquid in the thin layer is treated as symmetrical about the vertical

axis, quasi-steady, and dominated by viscosity. Heat is assumed to be transferred across the layer from the wall to the melting front by conduction. The volumetric flow rate, gradient of pressure, viscosity, rate of transfer of heat, thickness of the layer, and speed of melting are described by interrelated equations as functions of each other and of position.

The foregoing equations are combined and manipulated further to yield an equation for the pressure as a function of the melting speed and position, which is integrated to find the upward force exerted on the solid by the molten layer. The requirement of static equilibrium of the solid yields another equation for this force in terms of the gravitational acceleration, the densities of the solid and liquid, and the remaining volume of the solid, which can be closely approximated as a function of the melting distance with the help of the assumption that the thickness of the melting layer is much less than the radius.

The two equations for the force are combined to obtain a differential equation for the melting speed as a function of the melting distance. The time and distance variables are nondimensionalized by combining the effects of the parameters for the viscosity, density, heat of melting, gravitation, thermal conductivity, specific heat of the liquid, and the temperature difference into one multiplicative factor. The exact form of the equation is

$$\frac{d\xi}{d\tau} = (C/12)^{1/4} \left[(2-3\xi+\xi^3)/(1-3\xi^4+2\xi^6)\right]^{1/4}$$

where ξ and τ represent the nondimensionalized melting distance and time, respectively, and C is the multiplicative factor.

When the inverse of the quantity in brackets is approximated by a third-order polynomial, the equation can be integrated to obtain

$$\tau = (1/C)^{1/4} (1.56\xi + 0.279\xi^2 + 0.261\xi^3 - 0.0686\xi^4)$$

The nondimensionalized time τ_f to melt the entire mass is found by setting $\xi = 1$. This yields $\tau_f = 2.03\,(1/C)^4$.

This work was done by Parviz A. Bahrami and Taylor G. Wang of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Analysis of Gravity and Conduction Driven Melting in a Sphere," Circle 125 on the TSP Request Card.*
NPO-16758

More on Scattering From Dirty Mirrors

A mathematical model of scattering is expanded from visible to include infrared wavelengths.

A paper describes an extension of a mathematical model of scattering from a mirror slightly contaminated with particulates. The original version of the model, described in a previous issue of *NASA Tech Briefs*, applies to scattering at visible wavelengths. The updated version can be used to predict scattering at wavelengths from visible through infrared, based on measurements in the visible spectrum.

The basic model gives the bidirectional reflectance distribution function (BRDF) of the mirror in question at one wavelength in terms of the angle of incidence, the angle of scattering, and six parameters that characterize the condition of the surface. With proper adjustment of the parameters, the BRDF's predicted by the model agree very well with the BRDF's measured at a wavelength of 0.6328 μm at various angles of incidence on specimens of various roughnesses and degrees of contamination.

In the extended model, the parameter σ_1, which represents scattering from the particulate contamination, is modified to show the approximate increase of this scattering with increasing wavelength. For the purpose of extrapolation from visible to infrared wavelengths, acceptable accuracy is given by

$$\sigma_1 = \sigma_1'(\lambda/0.6328)^{1.12}$$

where $\sigma_1' =$ the value of σ_1 at a wavelength of 0.6328 μm and $\lambda =$ the wavelength in micrometers.

The principal term in the mathematical model of the BRDF is the power spectrum $W(p)$ of the surface-height distribution. In the extended version, this distribution is given by

$$W(p) = [2\sigma^2\ell/(1+p^2\ell^2)] + \sqrt{\pi}\,[\sigma_1'(\lambda/0.6328)^{1.12}]^2\ell_1 \exp(-p^2\ell_1^2/4) + \gamma\sqrt{\pi}\,[\sigma_1'(\lambda/0.6328)^{1.12}]^2\ell_1 \exp[-(p-c)^2\ell_1^2/4]$$

where $p = (2\pi/\lambda)(\beta - \beta_o)$; β and β_o are the direction cosines of incidence and scattering, respectively; σ is the contribution of the Lorentzian component of the surface-height distribution to the root-mean-square roughness; σ_1' is the Gaussian contribution to this roughness; ℓ and $*_1$ are the autocorrelation lengths of the Lorentzian and Gaussian, respectively; γ is a scaling factor; and both $\gamma\sigma_1^2$ and c are influenced by the combined effects of the angle of incidence and the contaminants.

This work was done by Yaujen Wang of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Scattering From Mirrors Contaminated by Particulates — II: an Extended Model," Circle 56 on the TSP Request Card.*
NPO-17490

Multiple-Vortex-Ring Model of a Microburst

Data from a wind-shear incident support a two-ring model.

A report discusses a multiple-vortex-ring mathematical model of a microburst, which is a strong downdraft that induces an outflow of strong winds near the ground. This low-altitude wind-shear phenomenon is a topic of continuing study because of its effect on the safety of flight.

The model was developed in conjunction with information from a severe wind shear encountered in August, 1985 at Dallas-Fort Worth airport. Data on instantaneous winds along flight paths were obtained from digital flight-data recorders on two airplanes: Delta Airlines Flight 191, which penetrated a microburst during its landing approach and crashed; and American Airlines Flight 539, which made a go-around and penetrated the same microburst at an altitude of 2,500 ft (762 m).

For each vortex ring in the model, there is an image ring below the ground to make the ground a stream surface. The potential-flow basis of the model is composed of time-invariant vortex-ring filaments embedded in irrotational flow. The viscous core of each vortex ring is modeled by distributing the vorticity radially outward from the filament by a small distance relative to the diameter of the ring.

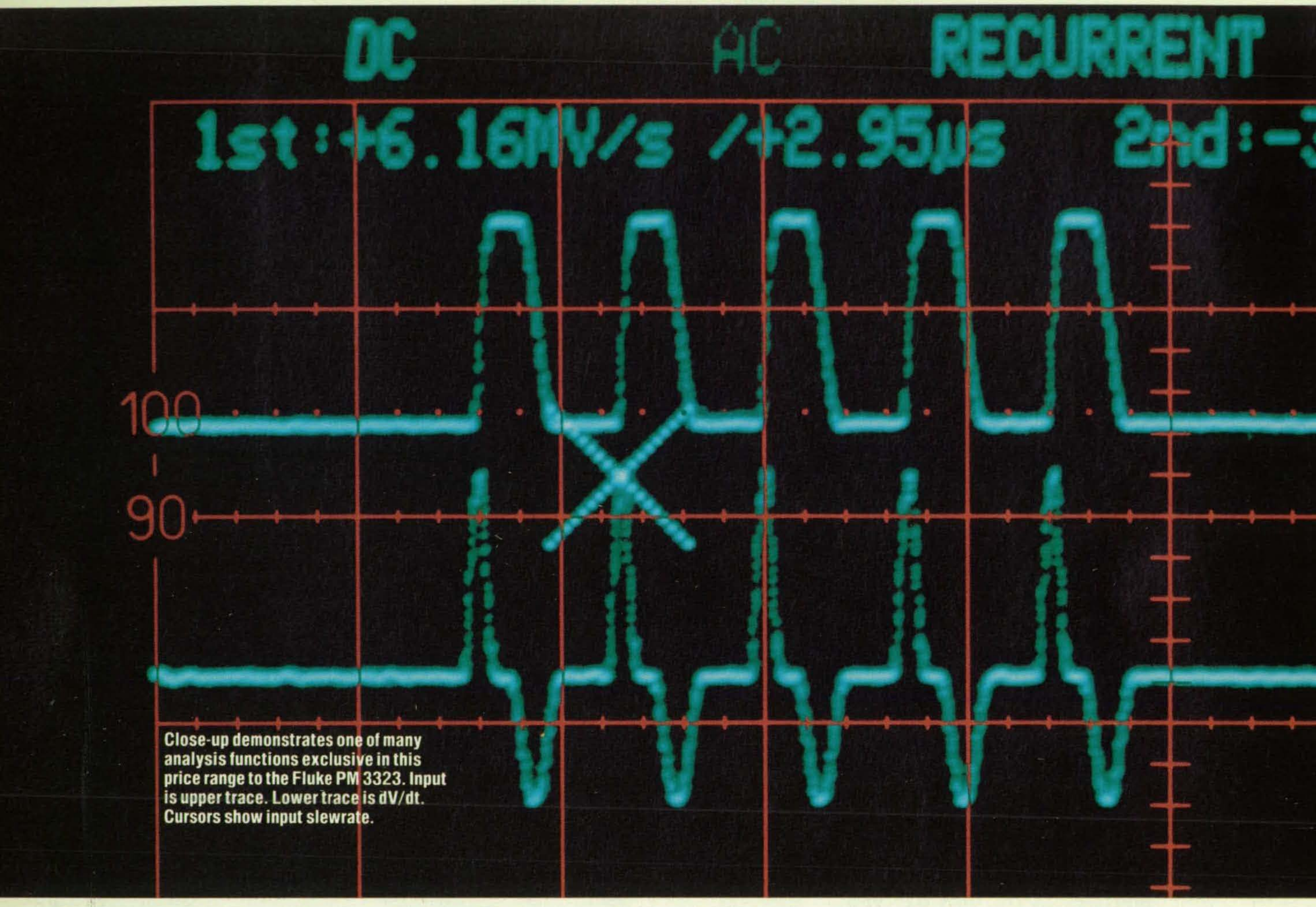
The velocity induced by each vortex ring is calculated by evaluating an algebraic expression representing the derivatives of its stream function. The velocity at any position in the flow field is the sum of the velocities induced at that position by all the rings, including the image rings. This sum of velocities is multiplied by the velocity-damping factor, which is used to model the viscous cores of the rings.

The model was verified by matching its predicted winds with the winds reconstructed from the data from Flight 539. A modified Newton-Raphson technique was used to estimate the sizes and strengths of the vortex rings. The parameters identified in this manner indicate a ring with a radius of 8,500 ft (2.6 km) and another ring with a radius of 1,700 ft (0.5 km). These parameters, when used in the multiple-vortex-ring model, provide a realistic microburst wind field that can be used in simulations and in studies of control systems.

This work was done by Thomas A. Schultz of **Ames Research Center**. *Further information may be found in AIAA paper A88-22511, "A Multiple-Vortex-Ring Model of the DFW Microburst."*

Copies may be purchased [prepayment required] from AIAA Technical Information Services Library, 555 West 57th Street, New York, New York 10019, Telephone No. (212) 247-6500. *ARC-12219*

FLUKE



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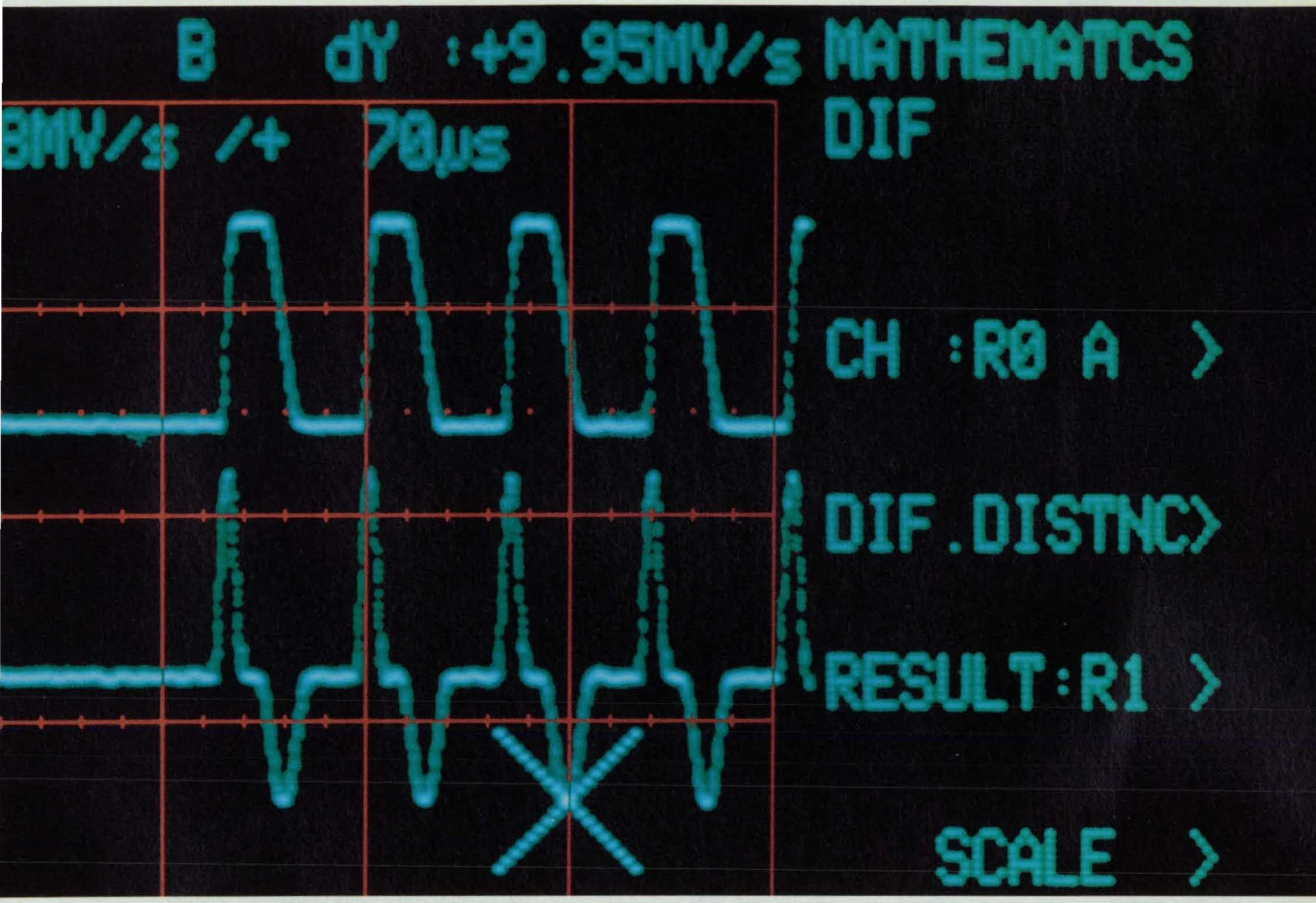

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Glitch Capture	Yes	Yes	No
Stop/Save on Difference	Yes	Yes	No
Analysis Functions (Int., Diff., Hist., Filter, FFT)	Yes	No	No
Math Functions (add, subtract, multiply, divide)	Yes	Multiply only	Yes
Measurement Functions (RMS, Freq., etc.)	Yes	Yes	Yes

FLUKE

Circle Reader Action No. 668

Materials

Hardware, Techniques, and Processes

Ceramic Wick for Capillary-Pumped Heat Pipe

The fibrous ceramic wick allows the choice of working fluid and high-temperature fabrication and/or operation.

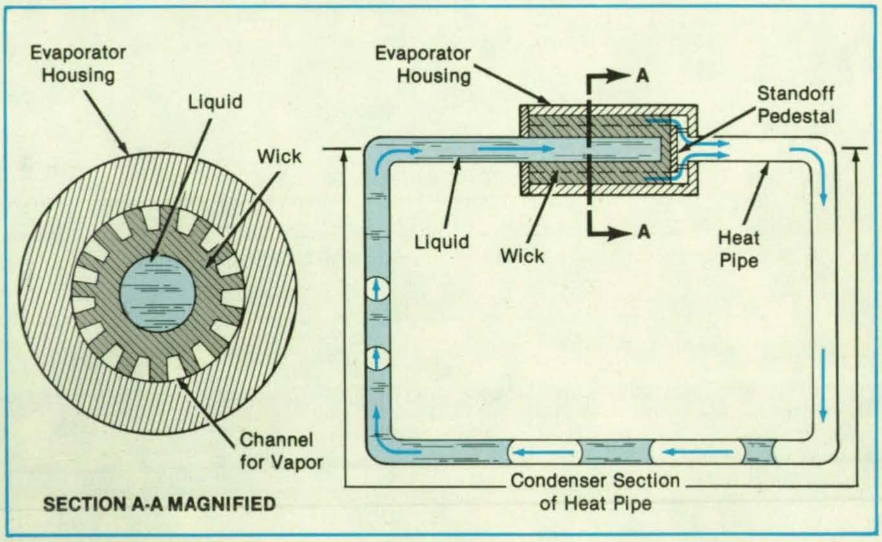
Goddard Space Flight Center, Greenbelt, Maryland

A ceramic heat-pipe wick is compatible, physically and chemically, with such thermally efficient working fluids as chlorofluorocarbons and ammonia. The wick material resists degradation at temperatures from −195 to +1,500 °C.

The wick material is a porous, permeable, open-cell ceramic made of silicon dioxide and aluminum oxide fibers (78 percent and 22 percent by volume, respectively) held together by boric oxide or another suitable inorganic binder. With an average size of less than 5 microns, the pores are small enough to ensure effective pumping but not so small that they impede fluid flow significantly. The material resists chemical attack by the fluid and does not contaminate the fluid or generate particles that could clog the system. It is easy to machine. Because it is not brittle, it is resistant to vibration.

The new material offers more-uniform pore size and, therefore, more-uniformly-distributed capillary action than do wire-mesh or sintered metal wicks, and, unlike them, does not corrode. It is more stable chemically than are cloth wicks. It is easier to fabricate and less prone to breakage than are glass-fiber or sintered ceramic wicks. Because the new material withstands high temperatures, it is not degraded by welding or soldering when it is assembled in an enclosure.

The silica/alumina wick capillary pumped loop is housed in the evaporator of a heat pipe (see figure). The working fluid, in liquid form, enters the bore of the wick through its open end. The liquid flows radially outward through the wick and evaporates from the radially heated outer finned surface of the wick. The working fluid, now in vapor form, flows through the channels between the fins and leaves the evaporator. The vapor gives off heat in the condenser section of the capillary loop, becomes liquid again, and flows back to the evaporator for recycling.



The **Liquid Refrigerant** fills the bore of the silica/alumina wick. After flowing by capillary action through the pores of the wick, the refrigerant evaporates from the finned outer surface of the wick and enters the heat pipe, flowing toward the condenser section.

This work was done by Benjamin Seidenberg and Theodore Swanson of **Goddard Space Flight Center**. *For further information, Circle 66 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Goddard Space Flight Center [see page 18]. Refer to GSC-13199

Making a Noble-Metal-on-Metal-Oxide Catalyst

A catalyst exhibits superior performance in oxidation of CO in CO_2 lasers.

Langley Research Center, Hampton, Virginia

A two-step process has been developed for preparing a platinum- or palladium-on-tin-oxide catalyst for the recombination of CO and O_2, decomposition products that occur in the high-voltage discharge region of a closed-cycle CO_2 laser. The recombination of these decomposition products is necessary, for they act to reduce the power and lead to unstable operation of the laser.

In the first step of this procedure, commercially-available, high-surface-area silica spheres, 10 μm in diameter, are placed in deionized water. Sufficient reagent-grade tin powder is added to coat the spheres with a monolayer equivalent of tin (IV) oxide. The water is boiled to deaerate the solids, and, after cooling, nitric acid is

added to obtain a 2.25-molar concentration. The mixture is slowly stirred and heated to 50 °C. A white suspension settles out, and the temperature is raised to 110 °C for overnight evaporation and drying.

In the second step, deionized water is added to the dried powder and boiled again for deaeration. Sufficient $Pt(NH_3)_4(OH)_2$ is then dissolved in hot, deionized water to obtain the desired fractional monolayer coverage of platinum on the surfaces of the spheres. This solution is added to the hot water containing the spheres and stirred slowly. To reduce the $Pt(NH_3)_4(OH)_2$ to platinum metal, six equivalents of formic acid are added, and the solution is heated to just over 100 °C for overnight evaporation and drying. The catalyst product is a gray-to-black powder consisting of a monolayer equivalent of tin (IV) oxide on 10-μm-diameter silica spheres, with the desired fractional coverage of a monolayer equivalent of platinum metal.

A thin layer of tin oxide is desirable not only to maintain the high surface area of the combination of the catalyst and the support but also if isotopic labeling of the tin oxide is needed. Isotopic labeling involves the removal of the normal oxygen isotope in tin oxide and reoxidation of the reduced surface with the rare isotope, oxygen-18. Since only a thin layer of tin oxide is involved, this reduction/oxidation step requires a minimum of oxygen-18. Also, all of the tin oxide is likely to be labeled with oxygen-18, a particularly important characteristic in maintaining the isotopic integrity of rare-isotope CO_2 in closed-cycle CO_2 lasers.

The high effectiveness of this catalyst was determined by tests and comparative characterization with a commercially available catalyst. The catalyst made by this process has a high B.E.T. (Brunauer, Emmett, and Teller) surface area and a high activity at moderate temperatures. It is 10 times as active as a commercially available catalyst under similar conditions.

This process is inherently clean in that excess reagents or products decompose and evaporate, leaving no soluble residue. Furthermore, the reactions proceed at temperatures low enough not to decrease significantly the high surface area of the catalyst. This process is also applicable to other noble-metal/metal-oxide combinations.

This work was done by Irvin M. Miller and Patricia P. Davis of **Langley Research Center**, *and Billy T. Upchurch of Science and Technology Corp. No further documentation is available.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 18]. Refer to LAR-13741.

Computer Programs

COSMIC: Transferring NASA Software

COSMIC, NASA's Computer Software Management and Information Center, distributes software developed with NASA funding to industry, other government agencies and academia.

COSMIC's inventory is updated regularly; new programs are reported in *Tech Briefs*. For additional information on any of the programs described here, circle the appropriate TSP number.

If you don't find a program in this issue that meets your needs, call COSMIC directly for a free review of programs in your area of interest. You can also purchase the annual *COSMIC Software Catalog*, containing descriptions and ordering information for available software.

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Computer Programs

These programs may be obtained at a very reasonable cost from COSMIC, a facility sponsored by NASA to make computer programs available to the public. For information on program price, size, and availability, circle the reference number on the TSP and COSMIC Request Card in this issue.

Physical Sciences

Removing Hidden Lines for Thermal Analysis

The user can visualize accurately the orientations of objects under analysis.

The TRASYS Hidden Line Program, TEKHIDN, was developed to aid the thermal engineer in viewing objects for thermal analysis. It is designed to be run in conjunction with the Rockwell International version of the TRASYS thermal-analyzer program. TEKHIDN generates images of three-dimensional structures without showing the background lines of the objects. The hidden-line-removal aspect of the program enables the user to picture accurately orientations of objects being studied. Thus, the thermal model can be tested for accuracy before more-costly runs are made.

TEKHIDN has three major parts: the binary data processor, the algorithm, and the plotting routines. The binary-data preprocessor interprets binary output from the TRASYS program. The algorithm selectively determines the visibility of a line. By choosing a few points on that line, enough information can be derived to analyze the validity of its presence in the three-dimensional figure.

Upon determination of the visible lines in the geometric figure, the program passes to its graphical portion. The routines involved in plotting the geometric data utilize Plot10 library routines. The output is displayed in graphical form on a Tektronix graphics-display terminal. Hard copies of the terminal display are desirable and can be made if a terminal hard-copy device is available.

The TEKHIDN program was developed in 1986. It is designed to be implemented on a DEC VAX minicomputer using VAX VMS level 4.2 to 4.5. A Tektronix terminal and the Plot10 library are required.

This program was written by R. Rivera and T. M. Johnson of Rockwell International Corp. for **Johnson Space Center**. *For further information, Circle 61 on the TSP Request Card.*
MSC-21401

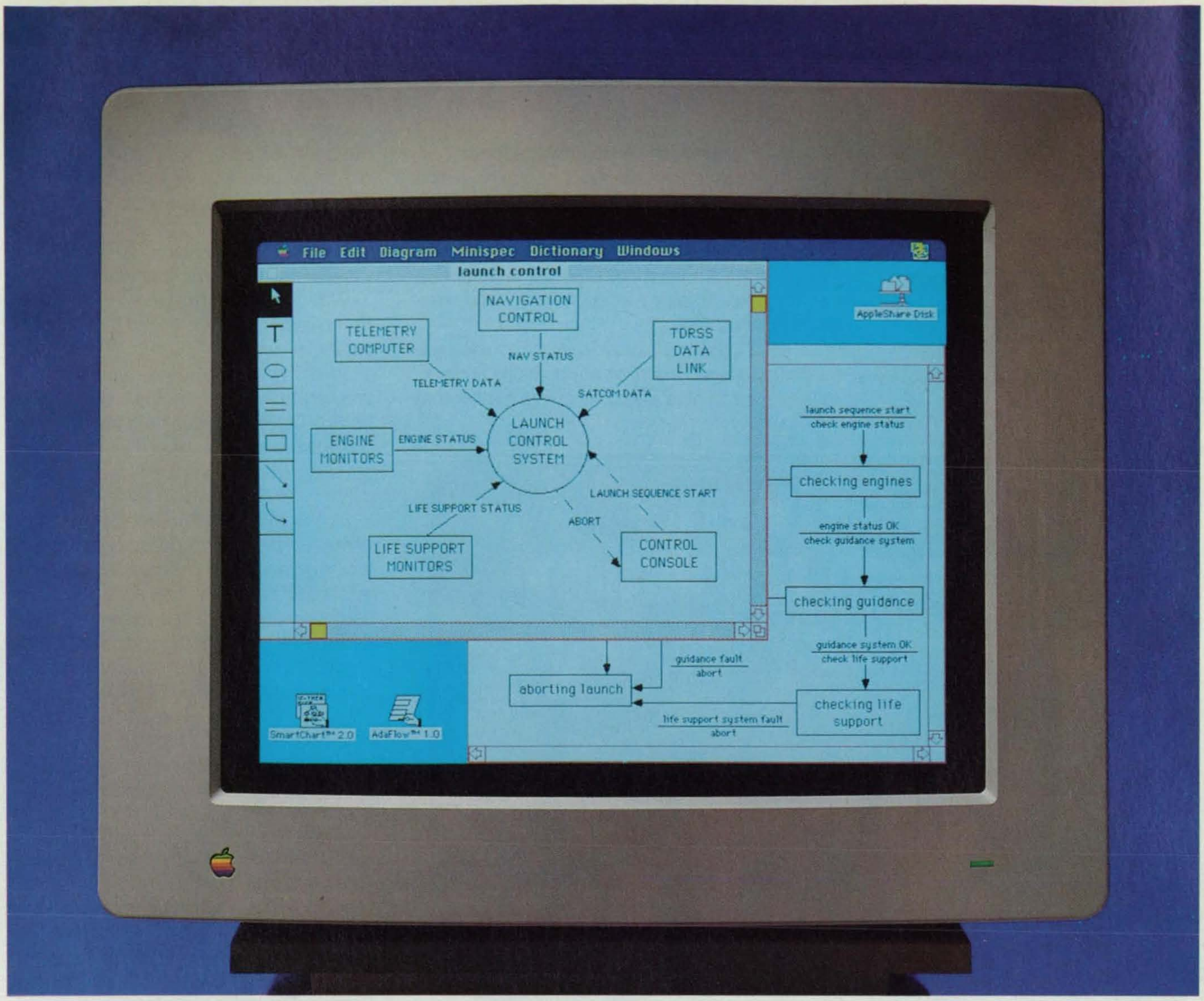
Tracing Rays in Laser-Fringe Anemometers

Effects of refraction are calculated by a simple program.

"OPTMAIN" is a simple ray-tracing computer code developed to quantify the refractive effects that result when a laser-fringe anemometer is used to observe flows through a window. These refractive effects can result in the following: (1) displacement of the probe volume, (2) "uncrossing" of the beams that make up the probe volume, and (3) a change in the angle of crossing of the beams.

The code calculates these changes for four different types of windows: (1) flat-plate windows, (2) simple cylindrical windows, (3) "general" axisymmetric windows, and (4) smooth general-surface windows. The first two window surfaces are described analytically, while the last two are described by use of a cubic-spline curve-fitting routine. Other input variables include the orientations of the laser beams, the angle of crossing, the wavelength, and the indices of refraction.

The code is currently operational on a VAX 11/750 computer. It is written in FORTRAN IV.



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Circle Reader Action No. 444

This program was written by Karl Owen of **Lewis Research Center**. *For further information, Circle 117 on the TSP Request Card. LEW-14535*

Mathematics and Information Sciences

C Language Integrated Production System

Versions are available for three different computers.

The C Language Integrated Production System, CLIPS, is a shell computer program for the development of expert-system computer programs. It is designed to enable research in and the development and delivery of artificial intelligence on conventional computers. The primary design goals for CLIPS are portability, efficiency, and functionality. For these reasons, the program is written in C. CLIPS meets or outperforms most artificial-intelligence software tools based on micro- and minicomputers.

CLIPS is a forward-chaining, rule-based language. The program contains an inference engine and a language syntax that provide a framework for the construction of an expert system. It also includes tools for the removal of errors from an application program. CLIPS is based on the Rete algorithm, which enables very efficient matching of patterns. The collection of conditions and actions to be taken if the conditions are met is constructed into a rule network. As facts are asserted either before or during a session, CLIPS matches the patterns of the number of fields.

Wild cards and variables are supported for both single and multiple fields. CLIPS syntax allows the inclusion of externally defined functions (outside functions that are written in a language other than CLIPS). CLIPS itself can be embedded in a program in such a way that the expert system is available via a simple subroutine call.

CLIPS version 4.2 represents a major revision of the CLIPS code to organize better the kernel and to lay the groundwork for additional features in the future. It has undergone extensive testing to ensure robust and reliable performance. Version 4.2 includes the rule compiler for run-time modules, an integrated MicroEMACS editor (for MS-DOS, VAX VMS, and UNIX systems), and an online help facility. The cross-reference tool has been vastly expanded to provide style checking and automatic verification.

Three machine versions are available. Each machine version includes the source code and the executable code for that machine. The DEC VAX version is line oriented. The PC and the Macintosh versions each contain a windowing variant of CLIPS as well as the standard line-oriented version. The mouse/window-interface version for the PC works with a Microsoft-compatible mouse or without a mouse. This window version uses the proprietary CURSES library for the PC, but a working executable code of the window version is provided. The window-oriented version for the Macintosh includes a version that uses a full Macintosh-style interface, including an integrated editor. This version enables the user to observe the changing fact base and rule activations in separate windows while a CLIPS program is being executed.

The CLIPS program is written in C for interactive execution and has been implemented on an IBM PC computer operating under DOS and on a Macintosh and a DEC VAX-series computer operating under VMS. The line-oriented version should run on any computer system that supports a full (Kernighan and Ritchie) C compiler or the ANSI standard C language. CLIPS was developed in 1986, and version 4.2 was released in July of 1988.

This program was written by G. Riley, C. Culbert, and F. Lopez of **Johnson Space Center**. *For further information, Circle 38 on the TSP Request Card.*
MSC-21208, MSC-21467, and MSC-21475

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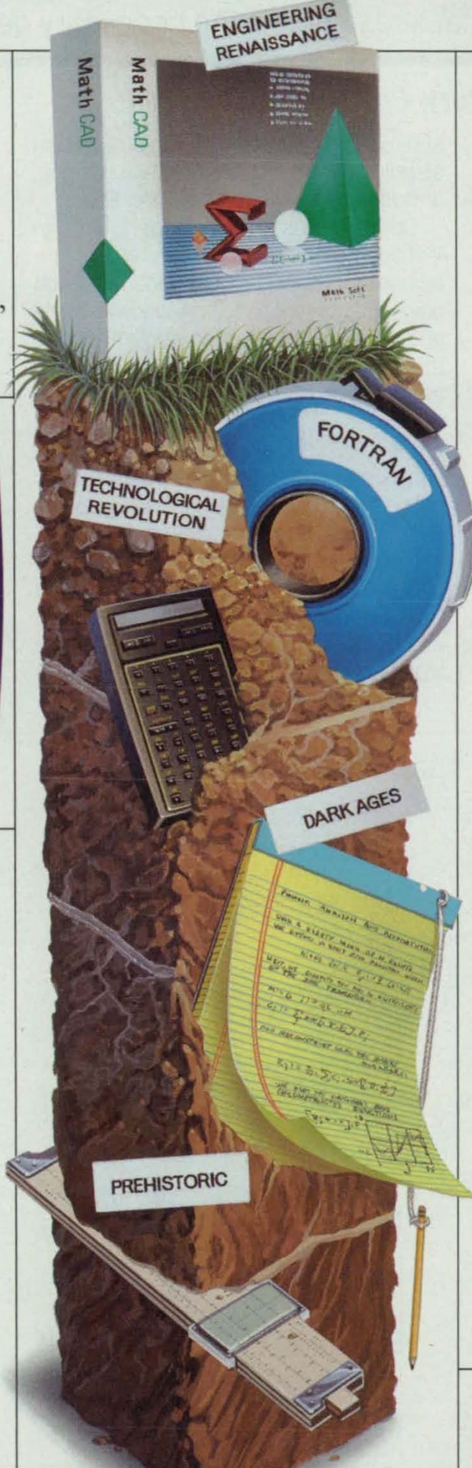

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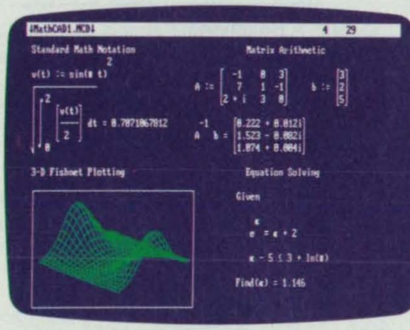

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PE

Mechanics

Hardware, Techniques, and Processes

Mounts for Selective Rotation and Translation

Blade-in-groove bearings are stacked to obtain the necessary degrees of freedom.

NASA's Jet Propulsion Laboratory, Pasadena, California

A mounting system allows panels to be tilted, rotated, and translated selectively. The system was developed for large solar reflectors or antennas composed of hexagonal panels about 6 ft wide and 6 in. thick (1.8 by 0.15 m). With the system, each panel can be tilted around two axes to focus the antenna. At the same time, each panel can translate along these axes to accommodate thermal expansion and contraction without affecting the focus.

A panel is mounted at three points (see Figure 1). Each point allows tilting around the axes of the sides of the triangle formed by the points. Not all points accommodate translation, however: if they did, each could shift in its plane and interfere with neighboring panels. Accordingly, the mount at point A allows rotation about axes AB and AC but no translation; the mount at point B allows translation along axis AB and rotation about axis BC; and the mount at point C allows both translation along, and rotation about, axes AC and BC.

Combinations of knife-edge blades in V-shaped grooves provide the requisite rotational and translational freedom at each point with low friction. At A, a lower blade and an upper blade at an angle of 60° to the lower blade allow independent tilt around axes AB and AC, but no translation (see Figure 2). At B, two blades are aligned perpendicular to axis AB to allow translation along axis AB, and a third blade at 60° is added to allow rotation around axis BC. At C, four blades are stacked. The lower two are aligned with each other; the upper two are also aligned with each other, but at 60° to the lower two. Mount C can thus tilt around axes BC and AC and translate along both axes.

This work was done by Earl R. Collins, Jr., of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 2 on the TSP Request Card.*
NPO-17686

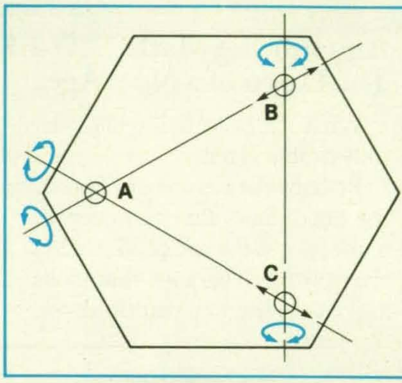


Figure 1. A **Hexagonal Panel Is Mounted** at three points. The mount at each point allows a unique combination of rotation and translation, with just the required degrees of freedom to accommodate thermal expansion and adjustments.

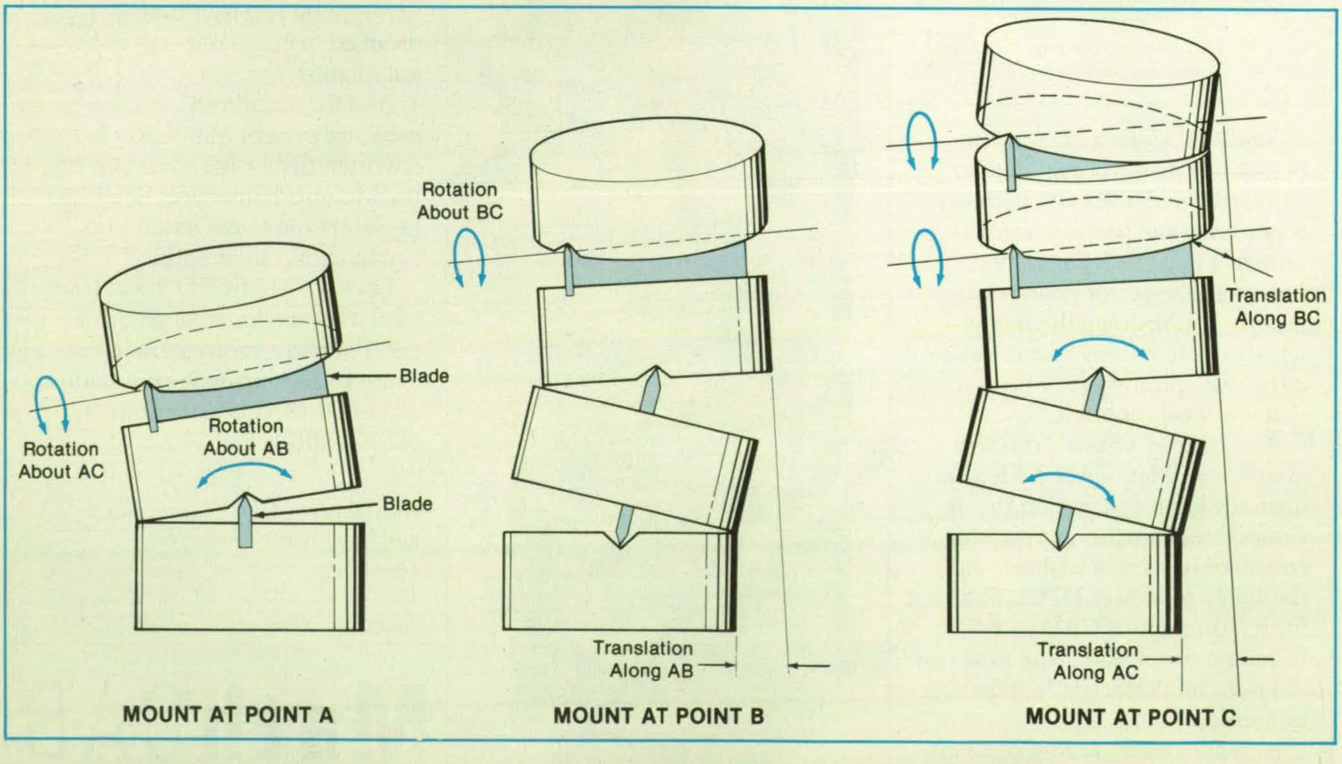


Figure 2. **Stacked Blades and Grooves** give the requisite rotational and translational freedom at each point. At A, two blades at 60° let the mount rotate around two axes without translating. At B, two parallel blades allow tilt and translation, and a third blade at 60° allows tilt around another axis without translation. The mount at C has two translational and two rotational degrees of freedom.

Cooling Shelf for Electronic Equipment

Heat-pipe action cools and maintains electronics at nearly constant temperature.

Langley Research Center, Hampton, Virginia

Electronic components mounted on flat shelves in spacecraft generate enough waste heat to require cooling. Typically, the shelves are made of solid aluminum, and the heat is conducted away through them. At high heating rates, the result is large differences of temperature (10 to 20 °C) between sources and sinks, and varying heat-input and cold-sink conditions create significant variances (20 to 40 °C) in temperatures of the surfaces of the shelves. Larger power levels can be accommodated only by increasing the thicknesses and weights of solid shelves or by reducing the temperatures of the cold sinks.

A system has been designed to control the temperatures of spacecraft shelves or baseplates by combining a honeycomb sandwich panel with a reservoir of noncondensable gas and processing the resulting device as a variable-conductance heat pipe (VCHP). As a result, the device provides a flat surface for mounting heat-dissipating electronics that is effectively cooled and maintained at nearly constant temperature.

The honeycomb VCHP can accommodate input heat up to several W/cm^2, and permits random placement of hot components; i.e., the hottest components do not need to be mounted closest to the cold wall. In addition, stable operation of electronics and protection from low temperature are provided by the variable-conductance feature, which can achieve a nominal control span of 3 °C.

A reservoir of inert gas is attached to a stainless-steel honeycomb panel near the condenser end of what is to be the heat pipe. The condenser end acts as the thermal interface with the wall of the spacecraft or similar cold sink. The device is processed with a predetermined amount of working fluid (methanol) and noncondensable gas (nitrogen). The amount of gas, the size and type of the reservoir, the input power, and the temperature of the sink determine the degree of control of the temperature of the source of heat.

The device acts as a very efficient conductor of heat during full load. At less than full load, the expanding noncondensable gas effectively blocks off increasing portions of the condenser to maintain the shelf at a nearly constant temperature. The reservoir can be either a hot or a cold type, depending on desired temperature-control limits and the level of complexity.

This device provides a high-conductance path for the transfer of heat from electronics to the cold walls of a spacecraft via heat-pipe action and maintains close control of the temperature of the shelf despite variations in conditions at the source and at the sink of heat. The honeycomb panel can provide the structural support and flat mounting surface of a conventional solid conducting shelf and can do so with reduced weight and superior thermal performance. Besides its use in aerospace applications, this technology is potentially useful in freeze drying, refrigeration, and air conditioning.

This work was done by Herbert J. Tanzer of Hughes Aircraft Co. for **Langley Research Center**. *For further information, Circle 37 on the TSP Request Card.*
LAR-13956

Hinged, Magnetic Holder for Radiographic Film

A specialized tool reaches a hidden position.

Marshall Space Flight Center, Alabama

A hinged holder equipped with magnets (see Figure 1) enables the positive, accurate, and repeatable placement and orientation of radiographic film at a hidden and otherwise inaccessible location. The holder is only a simple, specialized tool designed for the x-ray inspection of welds inside engine parts of a specific configuration. However, it serves as an example of the solution of problems of the type that often occur in the inspection of parts with cavities.

The film is taped to the holder. Four magnets attached to the holder enable the holder to be pulled along the inside wall of

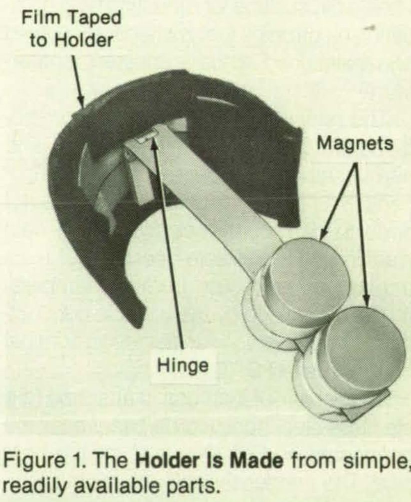


Figure 1. The **Holder Is Made** from simple, readily available parts.

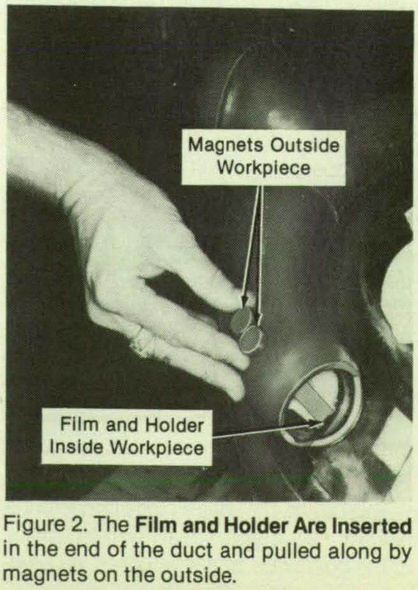


Figure 2. The **Film and Holder Are Inserted** in the end of the duct and pulled along by magnets on the outside.

the workpiece by magnets that are moved along the outside of the workpiece (see Figure 2). On the way to the location to be inspected, the holder is pulled up along a duct, past a flow splitter, and into a shell. The hinge at the front of the film holder allows the film to pass by the splitter.

The outside magnets are released to allow the holder to fall to the bottom of the shell. The outside magnets are then moved to grab the holder again, move it up the sidewall of the shell, and then move it down into the position for inspection. The hinge enables the film to rotate into the required position and orientation when the holder reaches the end of the shell. The holder is removed by reversing the foregoing sequence of motions.

This work was done by Darryl E. Pierce of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information Circle 104 on the TSP Request Card.*
MFS-29366

Machinery

Hardware, Techniques, and Processes

Remote-Manipulator Hand With Data-Processing Ability

An end effector contains electronics for processing sensory and control data locally.

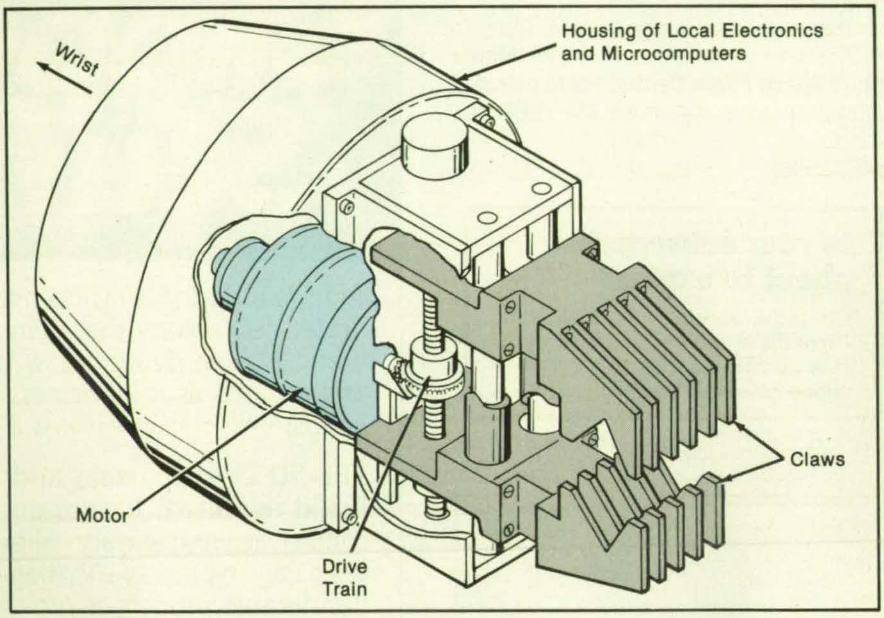
NASA's Jet Propulsion Laboratory, Pasadena, California

A "smart" hand for a remote manipulator not only senses forces acting on it and detects the presence of objects in its immediate vicinity but also processes the sensory data and controls its gripping claws. The hand thereby reduces the computational load on the control computer of the manipulator system.

The hand includes a wrist body and two opposing jaws with sets of claws that mesh with each other (see figure). Sensors in the wrist measure forces and torques on the hand in three orthogonal directions. Sensors in the claws measure gripping forces. Proximity sensors will be added to the claws to detect objects at distances up to at least 6.3 cm from the claw surfaces. These sensors give information on the distance of objects and provides the raw data for computation of the position, orientation, and velocity of the hand.

The grasping-force sensors on the jaws are strain gauges connected in bridge circuits. Eight additional strain-gauge bridges in the wrist measure forces and torque there. The proximity sensing will be done by light emitters and detectors arranged in pairs over the hand. Light reflected by an object from an emitter to a detector varies with the distance of the object. The local processor in the hand illuminates the emitters in sequence and simultaneously reads the digitized output of the corresponding detectors in the pairs.

The analog signals from the sensors are converted to digital signals and fed in parallel to a local processor in the hand. This processor puts the signals into serial form and sends them, via a slipring, to a signal processor on the stationary side of the rotary wrist. The signal processor computes parameters for the operator's display. The processor also receives command signals from the control computer. It interprets the coded commands, calculates the required hand response, and generates control signals for the dc motor that drives the hand.



The **Jaws of the Hand Open** as wide as 8.8 cm. A brushless dc motor operates the claws through a bevel-gear drive train and a pair of ball screws. The maximum grip force is 540 N, or about 120 lb.

This work was done by Antal K. Bejczy, Howard C. Primus, and Victor D. Scheinman of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 7 on the TSP Request Card.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

Edward Ansell,
Director of Patents and Licensing
Mail Stop 305-6
California Institute of Technology
1201 East California Boulevard
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Refer to NPO-16648, volume and number of this NASA Tech Briefs *issue, and the page number.*

Frequency-Domain Modeling of Dynamics of Helicopters

A comprehensive method combines and extends previous methods.

Ames Research Center, Moffett Field, California

A method for the identification, in the frequency domain, of the parameters of mathematical models of the dynamical behaviors of helicopters combines and extends several existing methods. The method focuses on linear-state-space (stability-and-control-derivative) models. Such models are needed for the design of control systems by use of state-space methods; for the detection and correction of errors in, and the improvement of, models used in simulations; and for comparisons of the characteristics of

wind-tunnel models with those of real aircraft in flight.

The method combines the measurement of frequency responses, calculation of transfer functions from the measured frequency responses, matching of frequency responses, determination of the accuracy of parameters of the mathematical model, and determination of the structure of the mathematical model, all as part of the comprehensive procedure illustrated in the figure. The measurement data are obtained in flight, then processed by advanced spectral methods based on the chirp-Z transform and concatenated/windowed time histories to obtain high-resolution and low-random-error frequency responses within each input-and-output pair. Multi-input/multi-output methods are available when simultaneous control excitations are present and are not fully correlated. The resulting nonparametric frequency-response functions are presented as Bode plots of magnitude (dB) and phase (degrees) versus logarithm of frequency.

The next step is transfer-function (parametric) modeling. Forms of appropriate transfer functions are established through visual inspection of the nonparametric frequency responses and through analytical modeling. A least-squares fitting routine is then used to determine those parameters in the transfer function parameters that best fit the magnitude and phase characteristics. The denominators of all of the transfer functions are constrained to be the same to ensure the physical consistency of the inherent (unforced) dynamics. No attempt is made to ensure physical consistency between the numerators of transfer functions that contain redundant aerodynamic information.

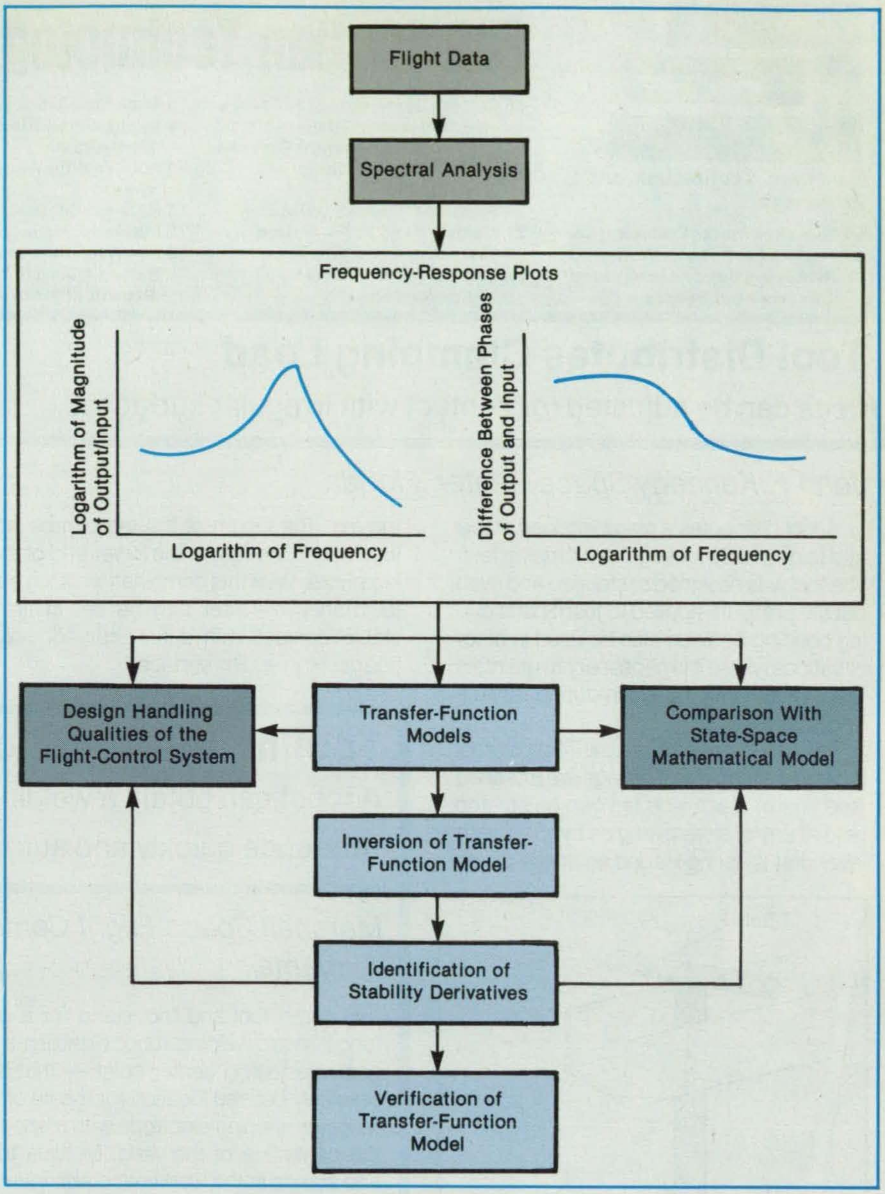
The leading coefficients in each transfer function are the control derivatives, and the equivalent time delays account for unmodeled dynamics and pure time delays inherent in the aircraft system. The results of both the nonparametric identification and the derived transfer-function models are useful for analyses of handling qualities, design of flight-control systems, and validation of mathematical models used in simulation.

The next step — inversion of the transfer-function model — is used as a simple startup procedure for the iterative stability-derivative solution, and takes the place of equation-error methods commonly used for this purpose. For the inversion, a simplified single-input/multiple-output formulation based on the phase-canonical form of the state-space equations has been found to be satisfactory.

The next step is identification of the stability derivatives. This is achieved through iterative multi-input/multi-output matching of the identified frequency responses with those of a linear mathematical state-space model. The Laplace transforms are taken, and allowances are made for the added time delay between the input and output in each input/output pair. The unknown stability derivatives are determined by minimizing the cost function of the weighted error between the previously identified frequency responses and the responses predicted by the state-space model.

The last step is verification of the state-space model via demonstration that it can predict the characteristics of responses to inputs that have forms different from those of inputs used to derive the model. For this purpose, the state-space model of the system is driven with flight data not used in the identification process.

This work was done by Mark B. Tischler of **Ames Research Center**. *For further information, Circle 124 on the TSP Request Card.*
ARC-12283



The **Comprehensive Frequency-Domain Method** for the identification of parameters of a mathematical model of a helicopter involves a synthesis of several prior methods.

Fabrication Technology

Hardware, Techniques, and Processes

Tool Distributes Clamping Load

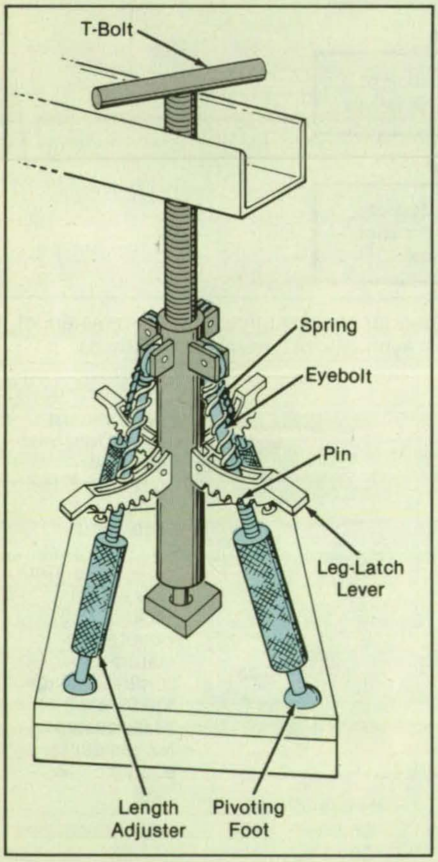
Legs can be adjusted for contact with irregular surfaces.

John F. Kennedy Space Center, Florida

A tool distributes a clamping load stably and fairly evenly among five clamping feet. The tool was designed to stabilize and even out the pressure applied to foam pads during bonding and can also be used in other situations where it is necessary to maintain fairly even clamping loads during fabrication processes.

The tool includes a central T-bolt clamping leg to which four side legs are attached (see figure). Each side leg can be set and held at any of several angles by a leg-latch lever that is spring-loaded against a pin on the leg. The length of the leg can be adjusted, and the foot at the lower end of the leg pivots. With this combination of leg adjustments, the feet can be set in firm, stable contact with a flat, curved, polyhedral, or irregular surface.

This work was done by Barry Wayne Spencer of Lockheed Space Operations Co. for **Kennedy Space Center**. *For further information, Circle 26 on the TSP Request Card.*
KSC-11420



Five Clamping Feet, four of which are adjustable, distribute the clamping load and maintain the clamping configuration during adhesive bonding or a similar fabrication process. The tool can be used to clamp nonflat as well as flat surfaces.

Tooling for Robotic Welder

A robot can obtain a welding tool and a position reference quickly and automatically.

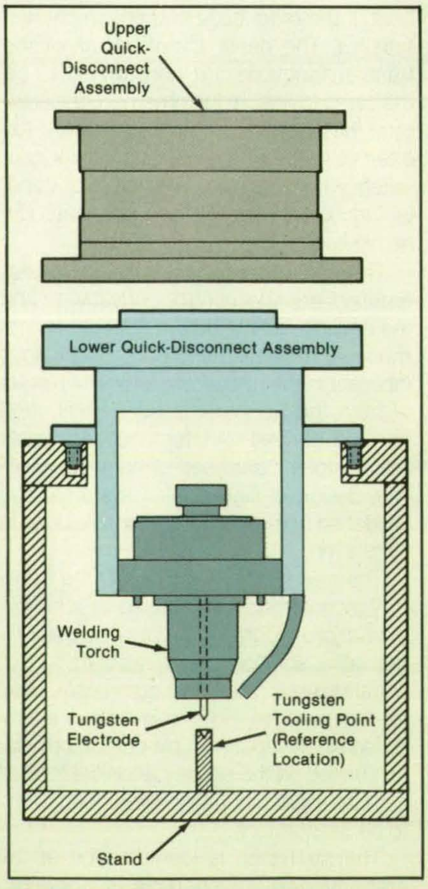
Marshall Space Flight Center, Alabama

A torch tool and tool stand for a gas/tungsten-arc-welding robot establish a repeatable tooling center point — that is, a precisely defined location for the tip of the tungsten welding electrode with respect to the centerline of the weld. Multiple tools and stands in the workspace also give the robot access to a variety of welding torches and reference positions. This feature saves time and makes it unnecessary for the operator to enter within the outer limit of motion of the robot arm.

Each stand in the workspace is a permanent changing station for its tool. A stand contains a tungsten tooling point that defines the reference position of the tip of the tungsten electrode (see figure). Thus, when the robot arm arrives at the stand and grasps the tool, the tool is prepositioned for an accurate weld; no additional calibration is needed.

The tool contains double-sealed quick-disconnect fittings with provisions for shielding gas, cooling water, and electrical power. The robot can therefore quickly engage a tool when it is ready to use the tool and just as quickly disengage the tool when it is finished.

This work was done by Jack L. Weeks of Rockwell International Corp. for **Marshall Space Flight Center**. *For further information, Circle 162 on the TSP Request Card.*
MFS-29557



The **Welding Torch Is Held** in a rigidly mounted stand. Quick-disconnect fittings give access to water, gas, and power ports.

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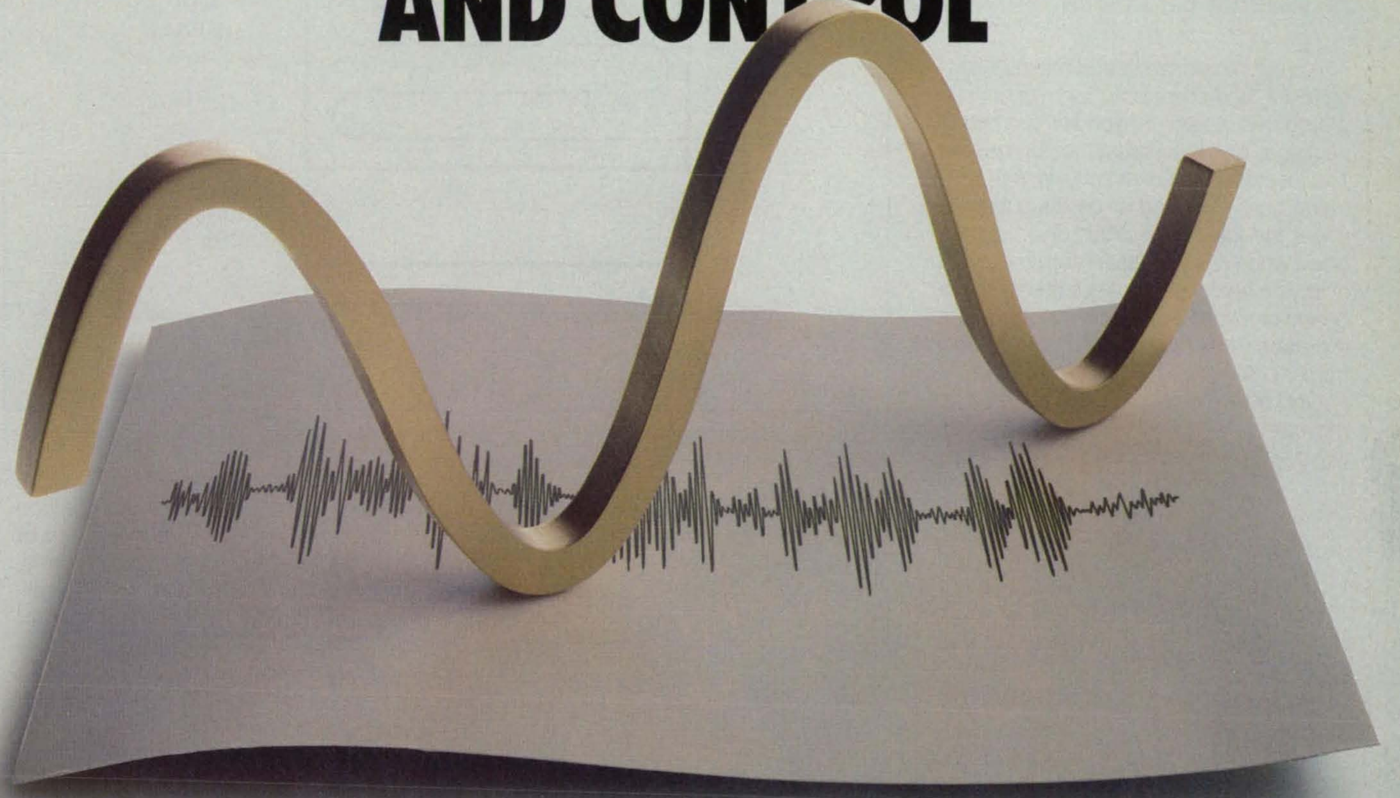

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Circle Reader Action No. 581

Removing Bonded Integrated Circuits From Boards

A heater interposed between chip and board softens the bond to ease removal.

NASA's Jet Propulsion Laboratory, Pasadena, California

A small resistance heater makes it easier, faster, and cheaper to remove an integrated circuit from a hybrid-circuit board, package, or other substrate for rework. The heater, located directly in the polymeric bond interface or on the substrate under the integrated-circuit chip, is energized when it is necessary to remove the chip. The heat it generates softens the adhesive or solder that bonds the chip to the substrate. The chip can then be lifted easily from the substrate.

Until now, a defective chip had to be removed by brute force — that is, by prying it away — or by heating it with a jet of hot air to soften the bond. The brute-force method can damage adjacent components as well as the chip itself. A broken chip, of course, makes the analysis of defects more difficult. The hot air can contaminate or damage the chip or the adjacent circuitry on the board.

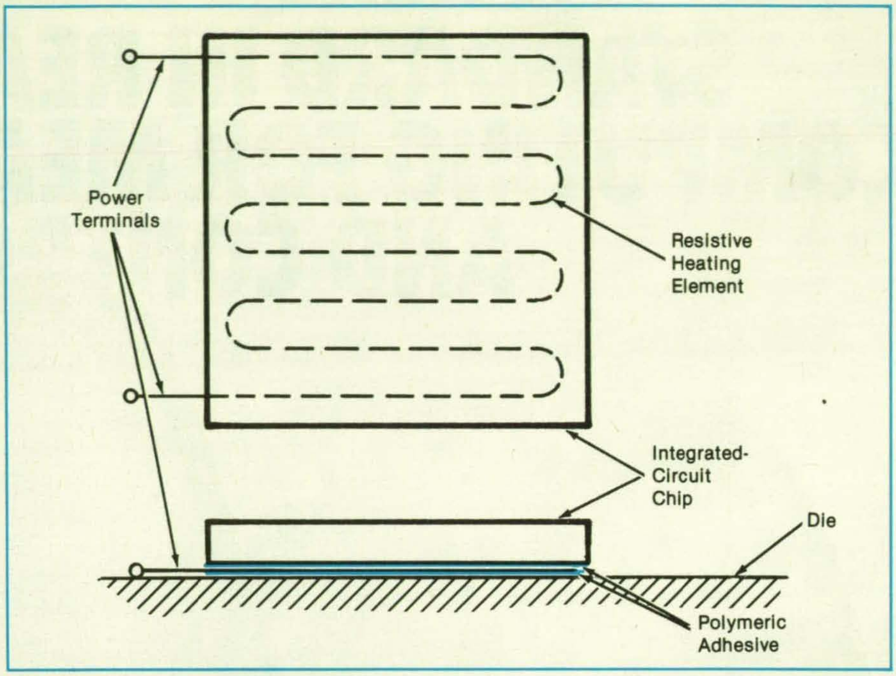


Figure 1. An **Insulated Resistive Heating Element** is embedded in the polymeric adhesive between an integrated-circuit chip and a die on which it is mounted.

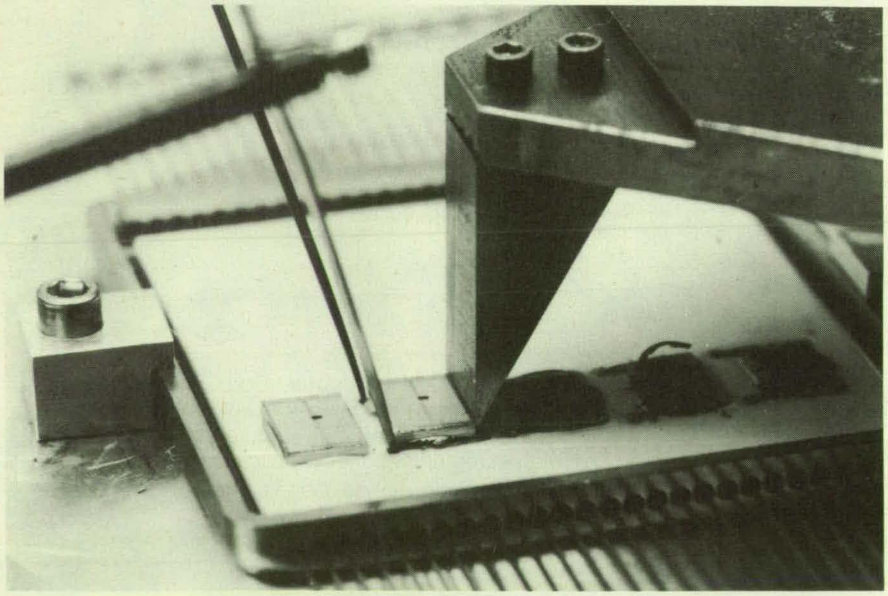


Figure 2. A **Pair of Probes** applies current to the terminals of a resistive heating element embedded in the adhesive in the manner shown in Figure 1. The heater softens the bonding material so that the bladed tool at the right can lift the chip away.

An insulated nickel/chromium-alloy resistance wire can be embedded in a serpentine pattern in the polymeric adhesive when the chip is attached to the substrate (see Figure 1). If it becomes necessary to remove the chip, a current of about 0.6 A can be applied at 1 to 2 V to heat the adhesive and soften it (see Figure 2). Alternatively, a thick-film resistive heating element can be deposited as part of the printed circuit on the substrate.

This work was done by John T. Rice of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 92 on the TSP Request Card.*
NPO-17031

Cutting Symmetrical Recesses in Soft Ceramic Tiles

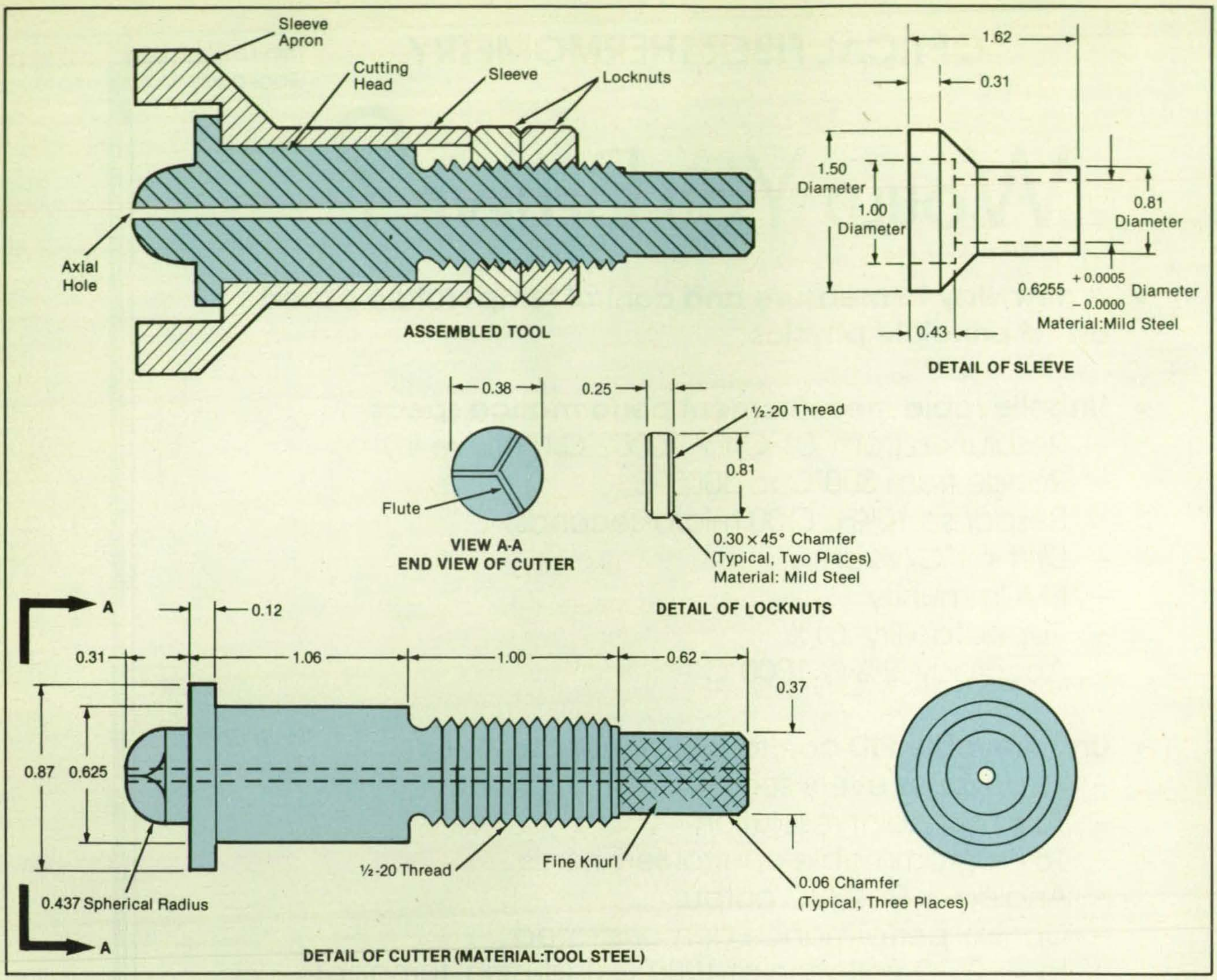
A tool makes smooth, rounded holes while protecting electrical leads.

John F. Kennedy Space Center, Florida

A simple tool cuts hemispherical recesses in soft ceramic tiles. The tool is designed to expose the wires of thermocouples embedded in the tiles without damaging the leads. It creates neat, precise holes around the wires.

The tool is used in place of such tools as dental picks, tweezers, spatulas, and putty knives, which were difficult and time consuming to use and produced rough, irregular recesses. Moreover, these other tools sometimes damaged the wires, the tiles, or both.

The tool consists of a three-flute hemispherical cutting head in a sleeve (see figure). The depth of cut can be preset by adjusting the protrusion of the head from the sleeve by tightening a pair of locknuts. An axial hole in the cutting head accommodates and protects the thermocouple leads as cutting proceeds. The user simply posi-



The End Mill Includes an Axial Hole to accommodate thermocouple wires embedded in the material to be cut. The wires pass into the hole without being bent or broken. Dimensions are in inches.

tions the cutter over the leads and turns it via a knurled knob at its outer end. The flutes dig away tile material with every turn, cutting deeper until the sleeve apron touches the surface of the tile and prevents further cutting.

If it is necessary to rework the tile at a thermocouple location, the technician loosens the locknuts, resets the cutter for deeper penetration, retightens the locknuts, and rotates the tool over the site. The cutter then removes old material at the site, exposing fresh thermocouple wires.

This work was done by Tony C. Nesotas and Brent Tyler of Lockheed Space Operations Co. for **Kennedy Space Center**. *No further documentation is available.*
KSC-11450

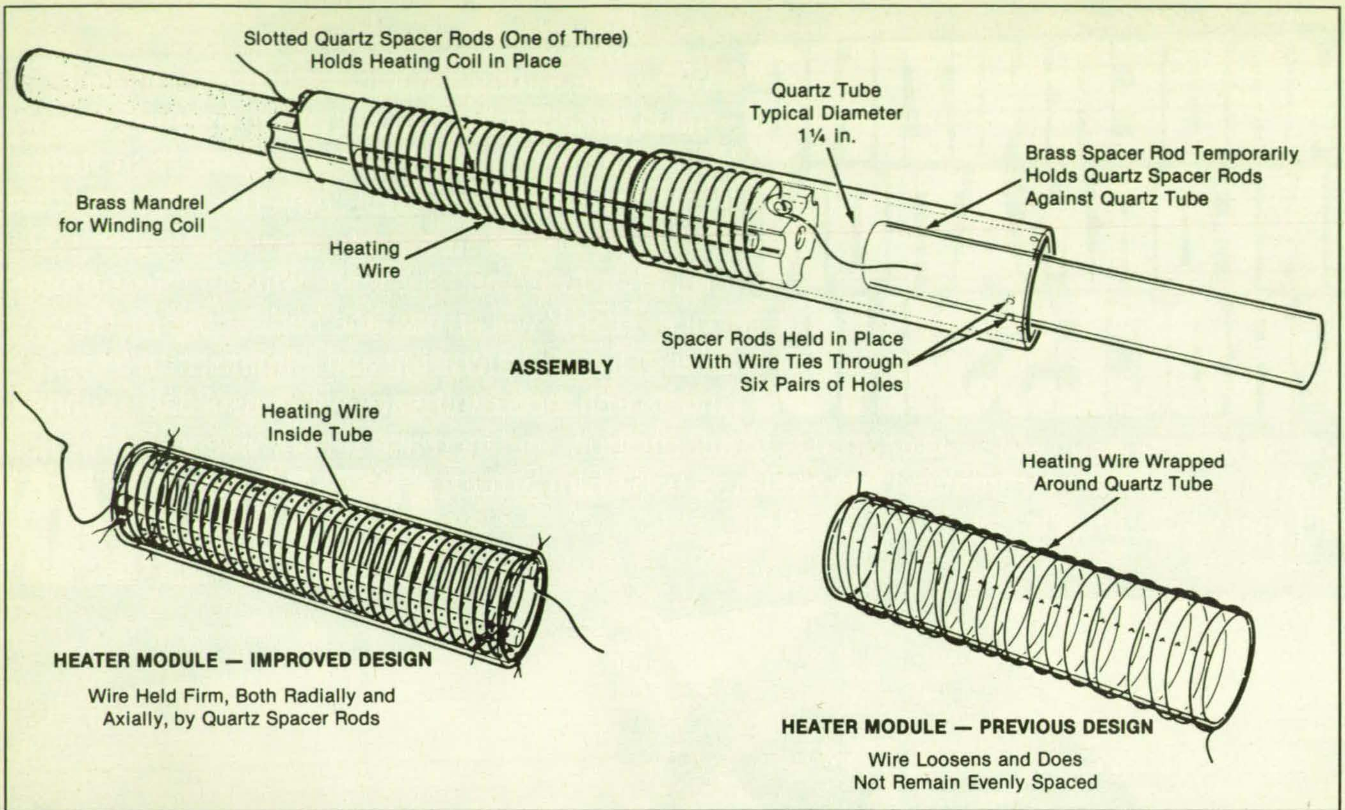
Improved Transparent Furnace for Crystal-Growth Experiments

A very uniform coil spacing assures better visibility and control of conditions.

Lewis Research Center, Cleveland, Ohio

A novel design and fabrication process for a transparent crystal-growing furnace have been developed. The spacing of the heating coil is very uniform compared to that of furnaces of other designs currently in use. A typical furnace of the new design consists of one or more heater zones in which heating wire is coiled around the insides of quartz tubes. An ampoule of material is supported inside the furnace (quartz tube/heater-wire assembly) by a guide wire. A crystal is then grown, for example, by directional freezing of the material in the ampoule. A distinct feature of the use of quartz is the capability of direct visual observation of the crystal-growth process during an experiment. A study of transparent electronic materials has been conducted in the new furnaces.

In older transparent furnaces, the heating wires are wrapped around the outsides of the quartz heater tubes (see figure). Spacing dimples are used to maintain the pitches of the heating coils. The disadvantages of dimpling are that the dimpling process is time-consuming and expensive, and the distance between dimples is usually a good deal larger than the width of the heating wire. Reduction of the dimple spacing results in even more trouble and expense. Also, dimples are easily broken. To wind the wire around a dimpled quartz tube, it is necessary to support the tube while maintaining tension between the wire and the tube. This tedious winding process is usually done by hand because it is difficult to support the quartz tube in any sort of vise or lathe and exert tension on it. The dimpling design results in nonuniform coil



The **Configuration and Assembly** of the old and new furnace designs are compared.

spacing which, in extreme cases, is manifested by electrical short circuits between turns of the heating wire. The nonuniform spacing and shorting result in unpredictable temperatures, which adversely affect the crystal-growth process.

In a furnace of the improved design, slotted quartz spacer rods are used to hold the heating coil accurately on the inside of a quartz tube. Slots in the spacer rods are easily made to very high precision by conventional grinding techniques. This helps maintain very accurate positioning of turns of the heating coil. A mandrel is used initially to wind the heating wire around the spacer rods. The mandrel is held in a glass-working lathe. The speed of the lathe can be adjusted down to a fraction of a revolution per minute. This enables very sensitive and precise positioning of the heating wire onto the mandrel assembly. Once the heating wire has been completely wound, the mandrel/wire/rod assembly is removed from the lathe and inserted in the quartz tube. The spacer rods are then attached to the quartz tube by wire ties at each end of the rods, and the mandrel is withdrawn. Combinations of these transparent quartz heater tubes are used to construct multi-zone crystal-growth furnaces.

This work was done by Bruce N. Rosenthal, Steve White, and Joseph M. Kalinowski of **Lewis Research Center**. *No further documentation is available.*
LEW-14895

Fluid/Gas Process Controller

The "Super Burper" controls fill fluids and isothermality during manufacture of heat-pipe devices.

Langley Research Center, Hampton, Virginia

During processing of heat-pipe devices, or after burn-in, if unwanted noncondensable gas is present, purging is required. Purging requires dumping the entire charge (fill) and then refilling (reprocessing), a very labor-intensive procedure. The fluid/gas controller, or "Super Burper", was developed to obtain precise fill quantities of working fluid and noncondensable gas in a heat pipe by incorporating a detachable external reservoir into the system during the processing stage.

The device consists of a flask reservoir with vacuum connections for attachment to a vacuum pump and to the heat pipe. A heat pipe can be filled with precise quantities of working fluid and noncondensable gas, and the procedure controlled accurately. The temperature and pressure in the reservoir are controlled to perform the intended function. The required amount of working fluid in, and the purging of unwanted gases from, a constant-conductance heat pipe, or the addition of a specified amount of noncondensable gas to a variable-conductance heat pipe can be controlled much more precisely with this device than was previously possible. By use of this in-situ heat-pipe-processing device, the optimum fill amounts can be determined while the heat pipe is instrumented and powered to perform at operating conditions. Also, the controller decreases rework time considerably in the addition and/or removal of working fluid and/or gas.

The controller simplifies the task of processing any type of heat pipe to stringent tolerances regarding isothermality. The controller was used on the heat pipe of the sideflow radiator panel at NASA Langley Research Center. The variation of temperature changed from 12 °C, after initial charge with methanol working fluid, to 1 °C, after implementation of the controller. The application of this device is best suited for high-quality, high performance heat pipes. To date, this device has been successfully implemented with various types of heat pipes, including vapor chambers, thermal diodes, large space radiators, and sideflows.

This work was done by Sergio Ramos of Hughes Aircraft Co. for **Langley Research Center**. *For further information, Circle 36 on the TSP Request Card.*
LAR-13955

Making Nozzles From Hard Materials

Electrical-discharge machining forms interior and exterior contours and internal channels.

Lyndon B. Johnson Space Center, Houston, Texas

A proposed method of electrical-discharge machining (EDM) would cut hard materials like silicon carbide into smoothly contoured parts. The concept was developed for the fabrication of the interior and exterior surfaces and internal cooling channels of convergent/divergent nozzles.

The method starts with a tubular section of the material, which must be electrically conductive. The tube is mounted on a fixture that can be rotated at a controlled rate in a wire-EDM machine. The wire can be translated with respect to the axis of rotation.

To cut the internal surface of a nozzle, the wire is passed through the hollow center of the tube. The tube is slowly rotated while the energized EDM wire removes material from the inside surface of the tube (see Figure 1). The wire is positioned at the precise skew angle θ and offset x that will yield the required hyperboloidal curvature and throat diameter.

To cut the outside surface, the EDM wire is repositioned outside the tube. It is reset to give the required curvature and wall thickness. The tube is once again rotated, and the wire removes material.

Coolant channels are started from the outer surface. The energized wire is drawn inward until it reaches the desired position of a channel — somewhere near the inner surface (see Figure 2). The tube is then rotated about the energized wire, which cuts the channel. To maintain a constant thickness between the channel and the inner surface of the nozzle, the wire would be set at the same skew angle used to shape the internal contour. Variations in thickness can be produced by varying the skew angle. When the channels have been cut, the entrance slots from the outer surface are filled with a brazing alloy or other filler.

The method will be less costly than the casting and grinding now used to shape nozzles. In addition, it will be more precise, will not introduce residual stresses, and will allow a more liberal choice of the shapes and orientations of cooling passages. Also, because the passages are not parallel to the flow of hot gas in the nozzle, a blocked passage is less likely to allow overheating.

In a variation of the method, the EDM wire could be replaced by an electrically heated wire for cutting large plastic molds or forms. In other variations a vibrating abrasive wire or a high-pressure water jet would be used for cutting.

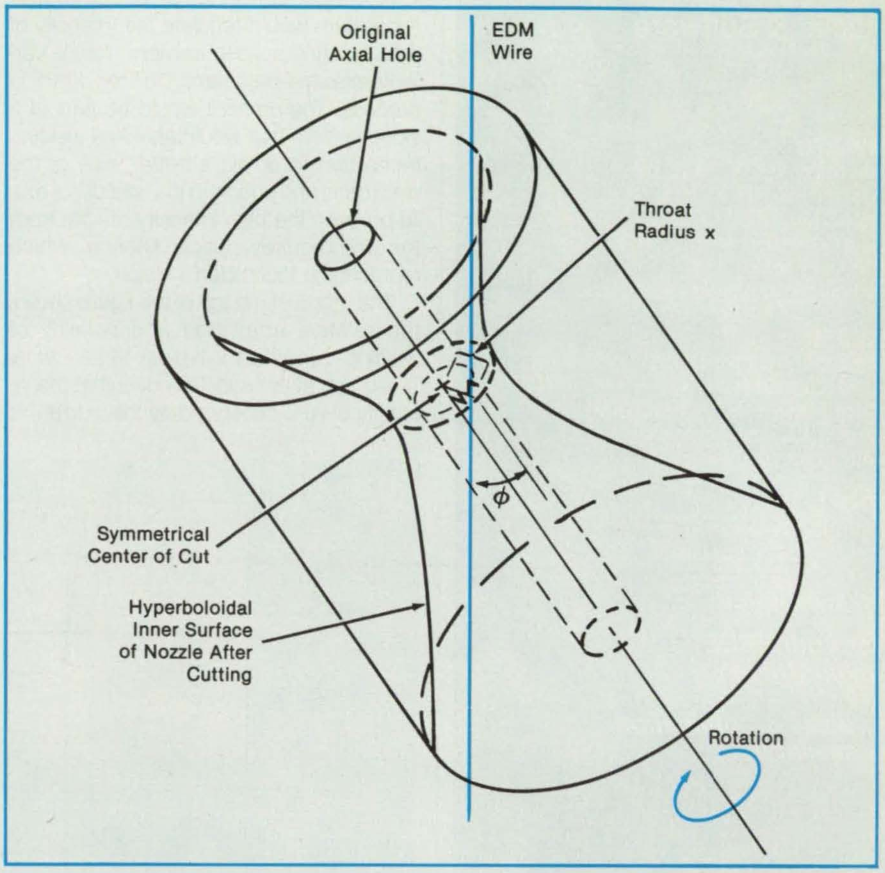


Figure 1. An **Electrical-Discharge-Machining Wire at Skew Angle θ** creates a hyperboloidal cavity in a tube. The wire is offset from the axis of the tube (and from the axis of rotation) by a distance equal to the throat radius.

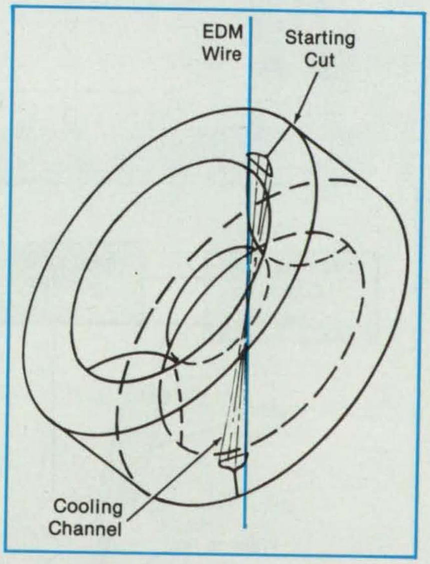


Figure 2. **Maintaining the Same Skew Angle** as that used to cut the hyperboloidal inner surface but using a larger offset, a cooling channel is cut in the material near the inner hyperboloidal surface.

This work was done by Dennis L. Wells of **Johnson Space Center**. *No further documentation is available.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center [see page 18]. Refer to MSC-21299

Shutter for VPPA-Welding Vision System

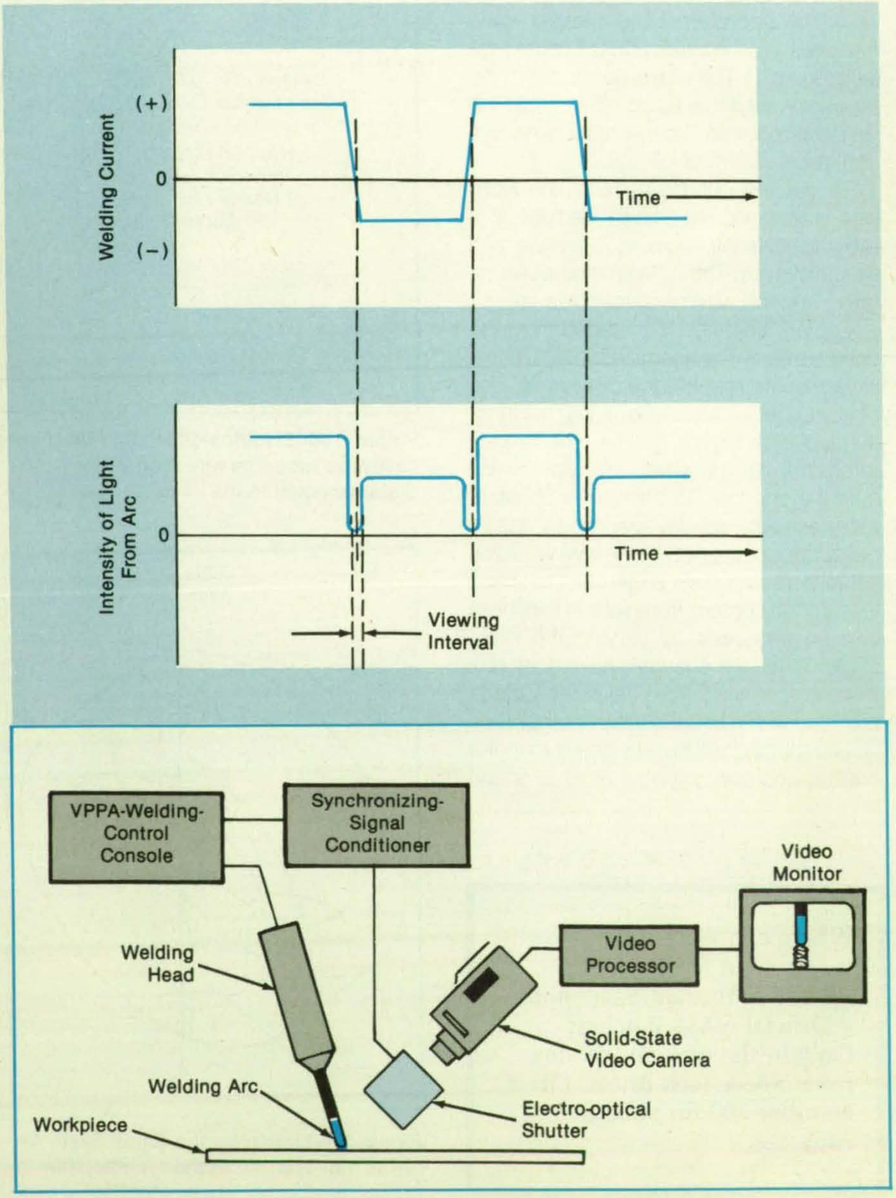
Optical input would be regulated according to welding current.

Marshall Space Flight Center, Alabama

A conceptual electro-optical shutter subsystem would regulate the intensity of light entering a video camera from a variable-plasma-pulse-arc (VPPA) weld in process. The camera would be part of a video system that would enable a welding technician to obtain a better view of the weld bead and puddle in the light of the arc. At present, the high intensity of light from the arc requires optical filtering, which restricts the technician's vision.

The graph at the top of the figure shows the relative amplitude and polarity of welding current in a typical VPPA cycle. The graph at the middle shows that the intensity of light generated by this current is approximately proportional to the magnitude of the current. The intensity during the positive and negative current peaks would overload the camera, "washing out" details of the weld bead. It is, therefore, necessary to restrict viewing to intervals of low illumination near the zero crossings of the current.

In the proposed subsystem, an electro-optical shutter would be placed between the welding arc and a solid-state video camera. The shutter would be controlled by a signal from the VPPA-welding-control console to open during the intervals of low illumination and close during the positive and negative current peaks. Alternatively,



The **Electro-optical Shutter** would be opened during the low-illumination viewing intervals near the zero crossings of welding current, preventing overloading of the video camera.

the control signal might be used as a bias signal to turn off the camera during high illumination. Thus, the camera would capture the image of the weld bead during periods of low illumination. The image would be processed through a video processor and displayed on a television monitor.

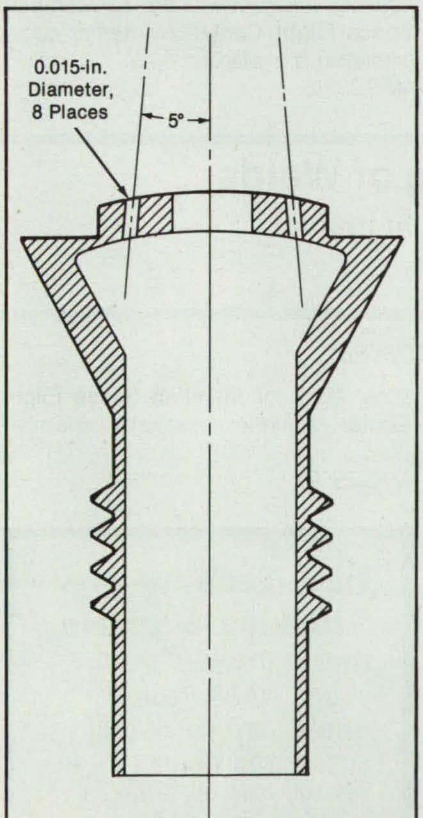
This work was done by Murray J. Lirette of Martin Marietta Corp. for **Marshall Space Flight Center**. *For further information, Circle 44 on the TSP Request Card. MFS-28267*

Multihole Arc-Welding Orifice

A simple modification of the welding torch improves the quality of welds.

Marshall Space Flight Center, Alabama

A modified orifice for variable-polarity plasma-arc welding directs the welding plume so that it creates clean, even welds on both Inconel* and aluminum alloys. The orifice differs from its predecessor in that it contains eight additional holes evenly spaced in a circular pattern around the central hole (see figure).



The **Modified Orifice of the Welding Torch**, shown here in cross section, includes eight holes to relieve the back pressure in the plasma. The quality of welds on ferrous and nonferrous alloys is improved as a result.

The holes, each 0.015 in. (0.38 mm) in diameter, are drilled with their centers 0.060 in. (1.52 mm) from the edge of the central hole and at a 5° angle toward the center. They eliminate the deflection of the arc caused by the back pressure of the plasma in the torch. Previously, the deflection produced a cutting action that sometimes weakened one side of a weld.

The holes also make it unnecessary to rotate the welding torch. Previously, rotation of the torch was the generally accepted way to correct the alignment of the arc.

*"Inconel" is a registered trademark of the Inco family of companies.

This work was done by Benji D. Swaim of Martin Marietta Corp. for **Marshall Space Flight Center**. *No further documentation is available.*
MFS-28322

Oxygen-Free Rinse Water for Electroplating

Deionized water through which nitrogen has been bubbled promotes a strong plated-metal bond.

Marshall Space Flight Center, Alabama

The removal of dissolved oxygen from deionized rinse water improves the bond between electroplated metal and the base metal. The oxygen is removed by bubbling nitrogen through the rinse water before it is used.

It is common practice in the electroplating industry to keep a metal workpiece immersed in water between electroplating steps to prevent oxygen atoms in the air from combining with some of the atoms on the surface of the metal. Even a thin oxide layer can adversely affect the quality of the bond between the base metal and the electroplate.

Deionized rinse water ordinarily contains a small amount of dissolved oxygen that can oxidize the base metal during a long immersion. Accordingly, electroplated parts for critical applications are customarily allowed to remain in deionized rinse water no longer than 55 seconds before being transferred to the next plating operation. However, in deionized water that has been purged of oxygen by bubbling of nitrogen, parts have been immersed for as long as 10 minutes without degradation of the bonds formed in subsequent plating.

This work was done by Ronnald Bodemeijer and Peter R. Newton of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*
MFS-29516

Acid Test for Annealing of Welds

A solution changes color if the heat-treated condition has been lost.

Marshall Space Flight Center, Alabama

A simple test indicates whether a welded joint has retained its postweld heat-treated condition after reworking, including rewelding and grinding. The test can be used instead of the usual Rockwell or Brinell hardness tests when the reworked surface is inaccessible to the hardness-testing apparatus or when the small surface imperfections created by the apparatus are unacceptable.

The new test begins with the application of an oxalic acid etching solution to the reworked surface. If the solution retains its black color, the welded area is still in the heat-treated condition. However, if the color changes to brown, the surface has been annealed by reworking and may need to be heat-treated again.

This work was done by Gary E. Deese and Joseph P. Ellgass of Rockwell International Corp. for **Marshall Space Flight Center**. *No further documentation is available.*
MFS-29598

Reinforced Honeycomb Panels

Lightweight reinforcement applied during fabrication helps panels resist buckling and bending.

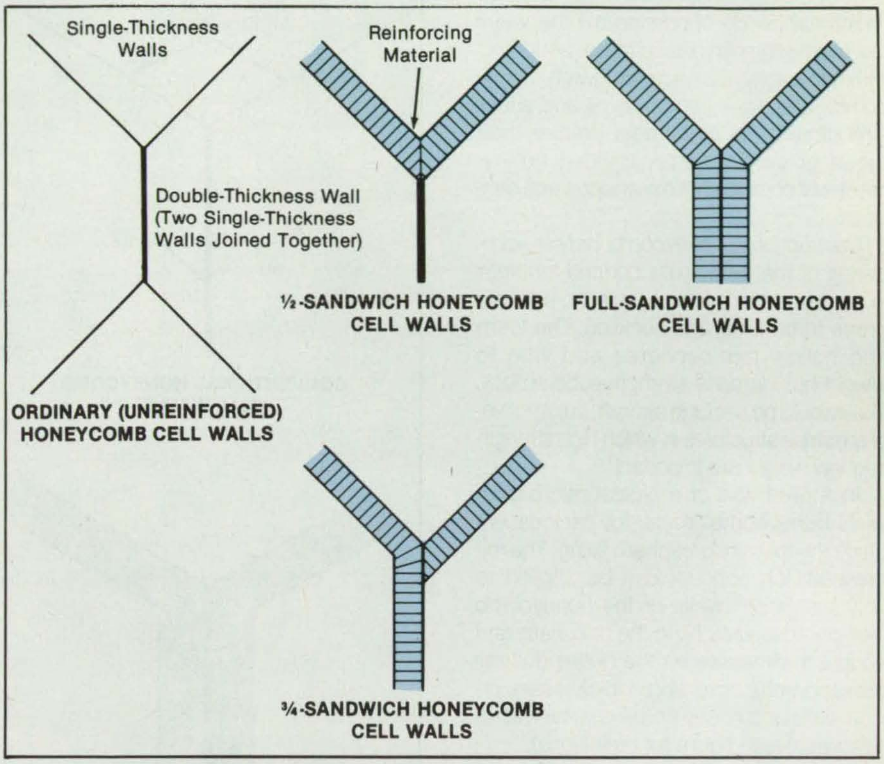
NASA's Jet Propulsion Laboratory, Pasadena, California

A new honeycomb panel structure has increased strength and stiffness with little increase in weight. In the new structure, some or all of the walls of the honeycomb cells are reinforced with honeycomb panels that have smaller cells, lightweight foam, or other reinforcing material (see figure).

The reinforced honeycomb is made, for the most part, by conventional fabrication techniques. However, strips of the reinforcing material are first bonded to the strips of the wall material to form reinforced cell-wall panels. The panels are then incorporated into the honeycomb structure by the usual adhesive-joining, pressing, and cell-opening operations.

An experimental version of the reinforced foam had 50 percent more compressive strength, 50 percent more shear strength along one axis, and 30 percent more shear strength along another axis than did the unreinforced version, with no increase in weight. The strong, lightweight reinforced panels could be used in aircraft, car and truck bodies, cabinets for equipment and appliances, and buildings.

This work was done by Balakrishna T. Bhat, Wesley Akutagawa, Taylor G. Wang, and Dan Barber of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 165 on the TSP Request Card.* NPO-17538



Honeycomb Cells can be partially or fully reinforced with lightweight foam. The reinforcement adds little to the weight of a honeycomb panel.

Insulated Honeycomb

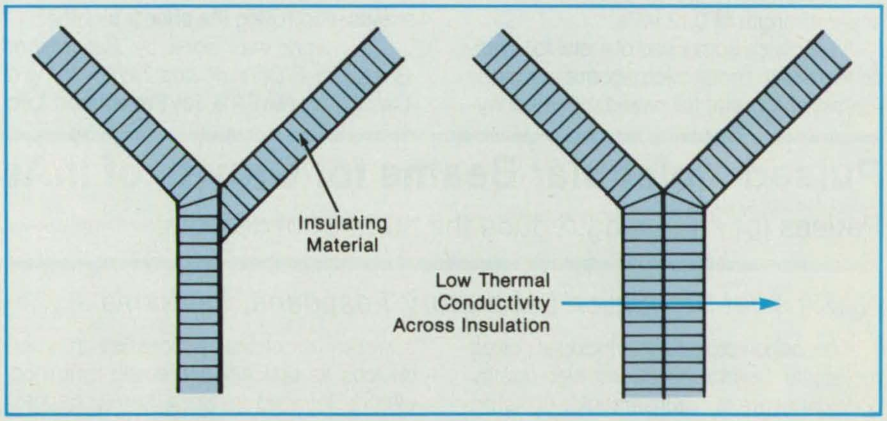
The flow of heat through the honeycomb is reduced.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed insulated honeycomb structure (see figure) would be similar to the reinforced honeycomb structure described in the preceding article. Panels of insulated honeycomb could be used to make supports for solar-energy collectors and radar antennas.

The insulating material could be lightweight foam, "microhoneycomb" filled with foam, or foam laminated between sheets, for example. The insulated honeycomb would be made similarly to reinforced honeycomb. Strips of insulating material would be affixed to the walls of the honeycomb cells prior to the conventional steps for the fabrication of uninsulated honeycomb.

This work was done by Balakrishna T. Bhat of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 1 on the TSP Request Card.* *NPO-17539*



Insulating Strips could be applied to the walls of honeycomb cells in single or double thicknesses. The thermal conductivity across each wall would thus be reduced.

Microsandwich Honeycombs

Fillings of foam and microspheres can increase the strengths of honeycomb panels.

NASA's Jet Propulsion Laboratory, Pasadena, California

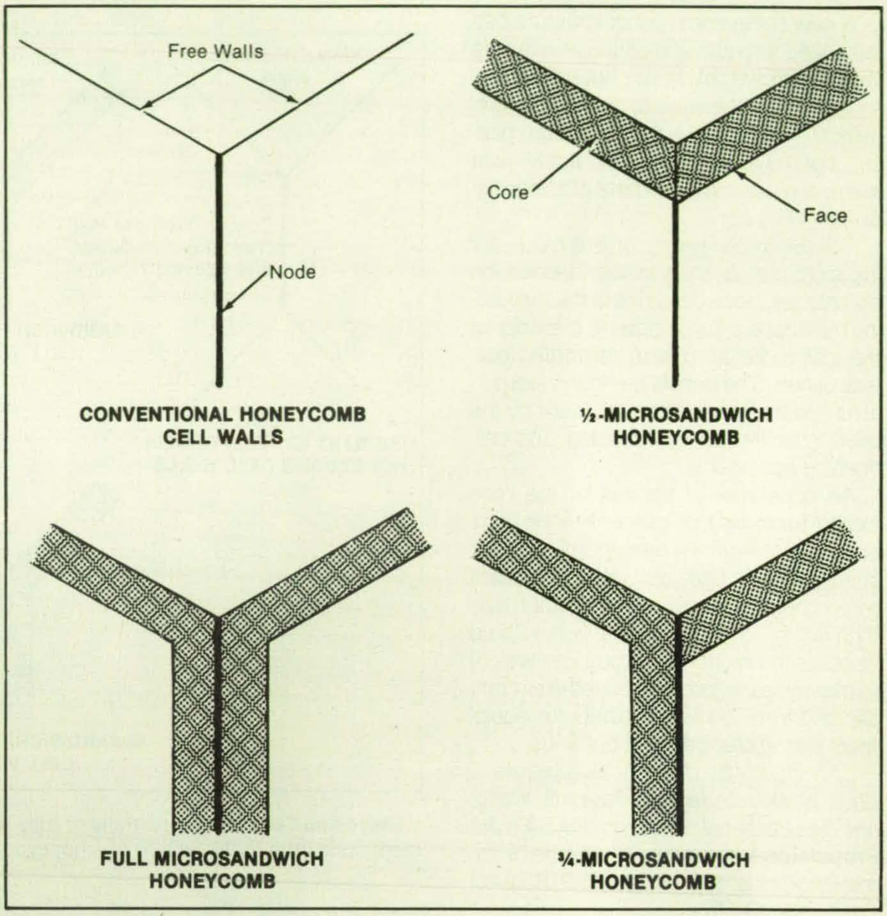
In a new type of honeycomb panel called "microsandwich honeycomb," the walls are filled with solid plastic foam reinforced with microspheres. Microsandwich honeycombs can have compressive and shear strengths 50 to 70 percent greater than those of conventional, unfilled honeycombs of comparable dimensions and densities.

Conventional honeycomb panels, consisting of metal-foil walls bonded together in honeycomb patterns, are notoriously prone to bending and buckling. The foam and hollow microspheres add little to weight but increase strength substantially. They would be useful in aircraft, automotive, and marine structures in which high strength and low weight are important.

In a filled wall of a typical microsandwich honeycomb, metal-foil facings enclose the foam/microsphere filling. The microsandwich concept can be applied to only the "free" walls of the honeycomb (half microsandwich), to the free walls and double thicknesses on the nodes (full microsandwich), or to single thicknesses on free walls and nodes (three-quarter microsandwich) (see figure for definitions).

In a demonstration of the effectiveness of the sandwich structure, a polymethacrylamideimide foam was sandwiched between sheets of paper and used for the free walls of a honeycomb. It was compared with a honeycomb in which paper was glued to the foam on one side only to eliminate the microsandwich effect. The paper/foam/paper honeycomb had a compressive strength of 0.43 MPa and a shear strength of 0.21 MPa. The paper/foam honeycomb was much weaker; it had a compressive strength of 0.165 MPa and a shear strength of 0.12 MPa.

A sandwich composed of metal foil, plastic foam with metal microspheres or other foams, and metal foil would make honeycombs that have strengths greater than those of their metallic counterparts. The sandwich could be manufactured by feeding sheets of foil from opposing rollers, pouring foaming constituents and/or microspheres into the narrow void between the sheets, and rolling the sheets together.



Microsandwich Honeycombs can take several cross-sectional forms. A conventional metal-foil honeycomb is shown for comparison.

This work was done by Balakrishna Bhat, Tim O'Donnell, and Taylor Wang of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 134 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA's Resident Office-JPL [see page 18]. Refer to NPO-17595

Pulsed Molecular Beams for Growth of InAs on GaAs

Pauses for annealing reduce the number of defects.

NASA's Jet Propulsion Laboratory, Pasadena, California

A deposition process that includes pulsed molecular beams produces high-quality epitaxial layers of indium arsenide (InAs) on gallium arsenide (GaAs) substrates. The layers can be made as much as 30 atoms thick without introducing excessive numbers of dislocations, despite the 7.4-percent mismatch between InAs and GaAs crystal lattices. The layers therefore offer superior electrical properties in such devices as optically addressed light modulators, infrared sensors, semiconductor lasers, and high-electron-mobility transistors (HEMT's).

Pulsing the beam gives newly deposited material time for annealing between pulses. During annealing, roughness on the surface disappears so that the material presents a smooth surface for the next layer. With fewer discontinuities to serve as sites for dislocations, the material deposited by the next pulse of molecules also tends to contain fewer imperfections.

A beam pulse lasts a few seconds — long enough to deposit ¼ to 2 atomic layers of InAs on the GaAs substrate. A slight excess of indium is provided in the

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Satellite Antenna Mechanical Design

You'll need experience in the mechanical design of satellite communication antennas, including expertise in composites for reflectors/feed tower structures, feed network layouts and RF components. A background in computerized mechanical/thermal analysis techniques is desired.

Satellite Antenna Electrical Design

You'll design spacecraft antenna systems including multiple and shaped-beams as well as feed arrays, networks and reflectors. Interfacing with electrical and mechanical design teams, you'll analyze antenna performance while participating in project reviews.

Spacecraft Integration & Test

You'll need at least 3 years experience in the integration, test verification and launching of spacecraft. Developing test plans and procedures, you'll define hardware requirements and evaluate test results. You must possess familiarity with spacecraft systems, software, mechanisms, power and/or communications sub-systems.

Satellite Communications Systems

Several opportunities exist for Communications Systems Engineers to perform system engineering duties including generation of specs and test requirements, I&T support, and launch/mission operations. A minimum of 3 years experience is required. Opportunities exist for:

Electrical Engineers—Responsibilities include spacecraft system electrical architecture design with emphasis on CR&T, harness and power sub-systems.

Mechanical Engineers—Involved in various mechanical design areas including structure, propulsion, thermal sub-systems and launch vehicle interfaces.

Mission Operations Engineers—To be involved in planning and conducting missions. Strong software experience is required.

Spacecraft Attitude Determination & Control

Requires 5 years experience including knowledge of 3-axis and momentum bias control techniques and architecture.

Spacecraft Propulsion Systems

As a senior member of our Propulsion Systems team, you'll provide direction in the design of unique program propulsion systems. You will be expected to ensure consistency of design approach as well as the technical definititon of a major propulsion sub-system. A minimum of 10 years experience with bipropellant and monopropellant systems is required including propellant and pressurant loading equipment. You must be well versed in the designs of components, including tanks, surface tension devices, rocket engines and pressure regulators.

Spacecraft Power Systems

You'll need to be familiar with battery and solar array technologies and power regulation topologies as well as possess demonstrated analytical skills enabling you to synthesize space power system requirements from mission requirements.

Spacecraft Power Electronics

Creating power regulation designs from systems requirements, your background must include at least 5 years experience with power conversion techniques, DC/DC converters and high-power analog circuits. Additionally, you must also be familiar with high reliability design techniques and military/aerospace design standards.

Spacecraft Thermal Systems

You'll need a BSME and a minimum of 3 years experience in the mechanical design and analysis of spacecraft thermal systems, both active and passive, including the construction of detailed multi-node computer models. Develop control techniques/placement of radiators, heaters, thermal finishes and multi-layer insulation. You must be familiar with test temperature prediction and balance testing of sub-system as well as spacecraft-level hardware.

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beam to ensure high migration rates in the film — and rapid smoothing — after the beam has stopped. During the off period, arsenic gas surrounding the film combines with the excess indium so that the film incorporates indium and arsenic in the stoichiometric proportions essential for good electrical properties.

A reflectance high-energy electron diffraction (RHEED) instrument monitors the surface of the wafer during the process. The annealing process requires from a few seconds to 2 minutes. When the RHEED specular reflectance reaches a maximum, annealing is complete. At that point, the molecular-beam epitaxy with indium and arsenic beams is resumed and another pulse of molecules impinges on the substrate. The cycle is repeated until an InAs layer of the requisite thickness has been deposited.

The pulsing/annealing technique reduces the variations in the thickness of strained quantum wells, yielding interfaces of better quality — a further benefit with respect to electrical performance in semiconductor devices. The technique is applicable to other epitaxial systems in which lattices are highly mismatched: GaAs on Si, InAs on Si, and AlAs on GaAs, for example.

This work was done by Frank J. Grunthaner of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 126 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA's Resident Office-JPL [see page 18]. Refer to NPO-17723

Delayed Shutters for Dual-Beam Molecular Epitaxy

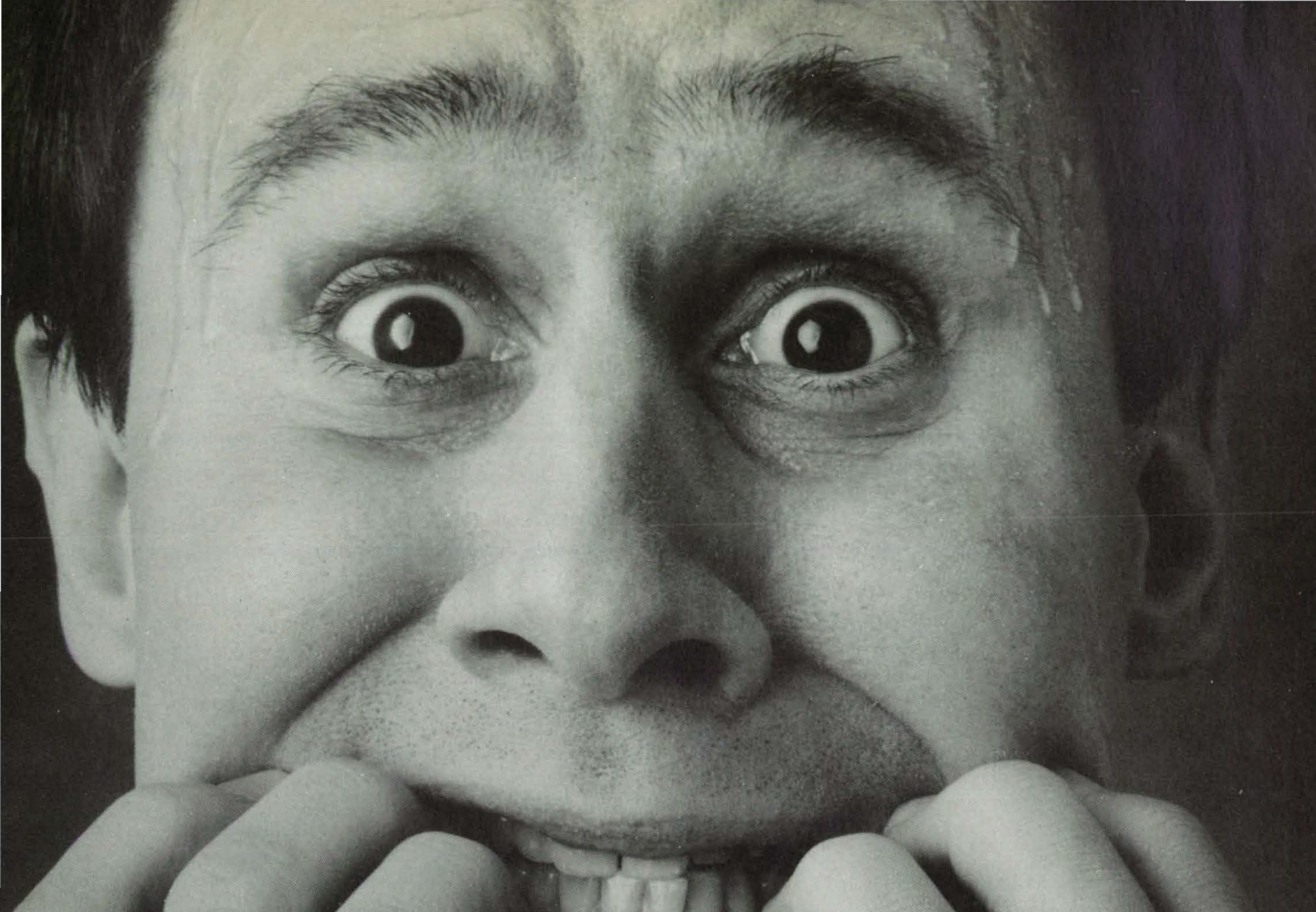
RHEED monitors and is used to control the proportions of elements.

NASA's Jet Propulsion Laboratory, Pasadena, California

A system of shutters for a dual-molecular-beam epitaxy apparatus delays the start of one beam with respect to another. Used in pulsed-beam equipment for the deposition of low-dislocation layers of InAs on GaAs substrates, the system delays the application of the arsenic beam with respect to the indium beam to assure the proper stoichiometric proportions on the newly forming InAs surface.

A reflectance high-energy electron diffraction (RHEED) instrument is used to monitor the condition of the evolving surface of the deposit. The RHEED signal is used to time the pulsing of molecular beams in a way that minimizes the density of defects and holds the lattice constant of InAs to that of the GaAs substrate.

Deposition is alternated with annealing in a cyclic process like that described in the preceding article, "Pulsed Molecular Beams for Growth of InAs on GaAs" (NPO-17723). After the annealing portion of the cycle, the surface reverts to an arsenic-stable condition in which a monolayer of arsenic accumulates on the surface. Therefore, the indium shutter is timed to open first and to remain open by itself until the In consumes the starting layer of As. The arsenic shutter is then opened also, and indium and arsenic are deposited on the surface together — this time with a slight excess of indium. After a few sec-



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onds, both shutters are closed so that the new film can anneal. The completion of annealing is monitored by RHEED. The cycle then begins again.

This work was done by Frank J. Grunthaner, John L. Liu, and Bruce Hancock of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 127 on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA's Resident Office-JPL [see page 18]. Refer to NPO-17724

Optoelectronic System Would Measure Profiles of Welds

Less inspection time and effort would be required.

Marshall Space Flight Center, Alabama

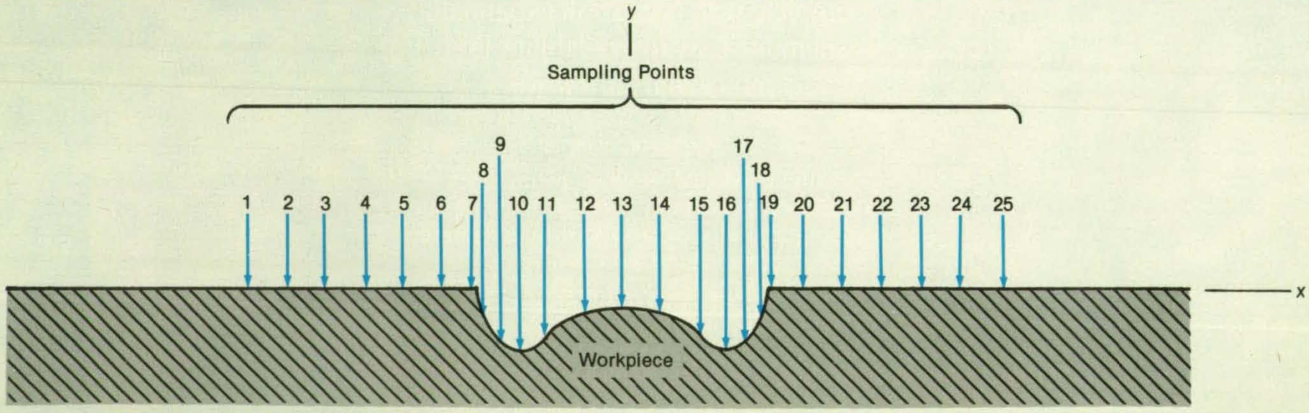
An optoelectronic system undergoing development at Marshall Space Flight Center is intended to measure the critical dimensions of a weld during the welding process. Until now, such a measurement has required the removal of the workpiece from the welding fixture for a time-consuming post-weld inspection. The new system could not only save considerable inspection time but could also enable the welding technician to make corrections during the welding process to bring a nonconforming weld back within specifications. Because the measurements would be taken without removing the workpiece from the welding fixture, it would not be necessary to reinsert and realign the workpiece to make a correction.

The system would provide data on the height of the surface at sampling points along cross-weld sampling lines spaced at intervals of 0.1 in. (2.54 mm) along the weld. Each sampling line would be formed by projecting a laser beam across the weld immediately behind the weld puddle. A charged-coupled-device video camera would view the sampling line and transmit the image to image-processing and display equipment.

The processor would translate the sampled data from the image into data on the profile of the weld bead. In addition, it would calculate measures of the underfill, depth and width of undercut, peaking, mismatch, and symmetry and centering of the weld bead (see figure). The system might also be made to examine the coincidence of the second welding pass with the first welding pass (seam tracking). The one-dimensional accuracy of a laboratory version of the system is 0.001 in. (0.025 mm); the accuracy of a practical version is expected to be close to 0.005 in. (0.13 mm).

This work was done by C. B. Dikinson and J. B. Hunt of Martin Marietta Corp. for **Marshall Space Flight Center**. *For further information, Circle 63 on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 18]. Refer to MFS-28385



Parameter	Defining Equation
Width of Weld Bead	$x_{19} - x_7$
Underfill	$(y_7 + y_{19})/2 - y_{13}$
Centering of Bead	$(x_{18} - x_8)/2$
Depth of Left Undercut	$y_7 - y_{10}$
Depth of Right Undercut	$y_{19} - y_{16}$
Width of Left Undercut	$x_{11} - x_8$
Width of Right Undercut	$x_{18} - x_{15}$
Mismatch	$[(y_1 - y_7) - (y_{19} - y_{25})]/2$
Symmetry of Weld Bead	$(y_{13} - y_{12}) - (y_{13} - y_{14})$
Peaking (Dihedral Angle Between Welded Plates)	$\tan^{-1}[(y_7 - y_1)/(x_7 - x_1)] - \tan^{-1}[(y_{25} - y_{19})/(x_{25} - x_{19})]$

The **Height of the Surface** (*y*) is measured as a function of position across the weld (*x*) at the numbered sampling points immediately after the initial welding pass. The *x* and *y* coordinates of the samples are then used to calculate parameters of the weld. Similar measurements can also be taken of the preweld fitup and the final welding pass.

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Mathematics and Information Sciences

Artificial Intelligence Controls Tape-Recording Sequence

Scarce recording space is allocated optimally.

NASA's Jet Propulsion Laboratory, Pasadena, California

A developmental expert-system computer program is intended to schedule the recording of large amounts of data on a limited amount of magnetic tape. Although designed primarily for use on the Voyager Spacecraft, the program is also applicable to planning and sequencing in industry; for example, in the scheduling of shipping containers or freight cars.

In the spacecraft application, data are recorded on tape when there is a need for subsequent or protectively redundant transmission or retransmission. The knowledge base of the program incorporates the expertise of a skilled sequence planner so that the recording sequence can be automated to minimize the cost, allocate the scarce tape recording medium optimally, preserve the recorded data until they are no longer needed, and standardize performance.

The program schedules recording using to two sets of rules. The first set of rules incorporates knowledge of the locations for the recording of new data and includes rules, such as the following:

1. New data can be recorded over old data only if the old data have already been played back.
2. To reduce the complexity of playback, similar types of data must be recorded contiguously.
3. Engineering data from fault-protection algorithms are always recorded on tracks seven and eight, and other data are recorded on these tracks only when all the other tracks are full. When other data must be recorded on these tracks, it is with the understanding that they could be overwritten at any time prior to playback. Therefore, the data with the lowest priority will be selected for recording on these tracks.
4. Data from a single image are always recorded on a single track. (If an image is recorded across the end of one track and the beginning of the next track, a wide horizontal band will be missing from the image at the change in track.)
5. New data should be recorded over data that have been played back least recently, so that if transmission is poor during the first playback it is possible to request a second playback of any data still on tape.

The second set of rules incorporates knowledge about issuing commands to the recorder, such as the following:

1. Commands should never be issued during turnaround at the beginning or end of the tape because these commands will be ignored. In the event of doubt, redundant commands can be issued.
2. The tape should never be left in one position for more than one month. If no recording takes place during a month, the tape should be run from end to end.

The knowledge base is programmed by use of a commercial expert-system shell. The inference engine of the shell reasons by backward chaining to produce a goal-driven search for applicable constraints. These constraints are then used in conjunction with information on data segment size to find a location on the tape at which the data can be recorded.

Input to the program consists of a list of new data (including preferred or default locations for certain items), a list of items and locations currently on the tape, and a list of items that have been played back. Output from the program can take the form of either a sequence or a specification of problems that prevent a sequence from being generated. Examples of such problems include requests to delete certain items from the list because of insufficient space on the tape, or requests to relax certain constraints based on the output of a knowledge source that prioritizes the constraints and selects those with the lowest priority for relaxation.

This work was done by Ursula M. Schwuttke, Roy M. Otamura, and Lawrence J. Zottarelli of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 27 on the TSP Request Card. NPO-17700*

Simulation of Combat With an Expert System

A proposed system would give combat-game players qualitative analyses.

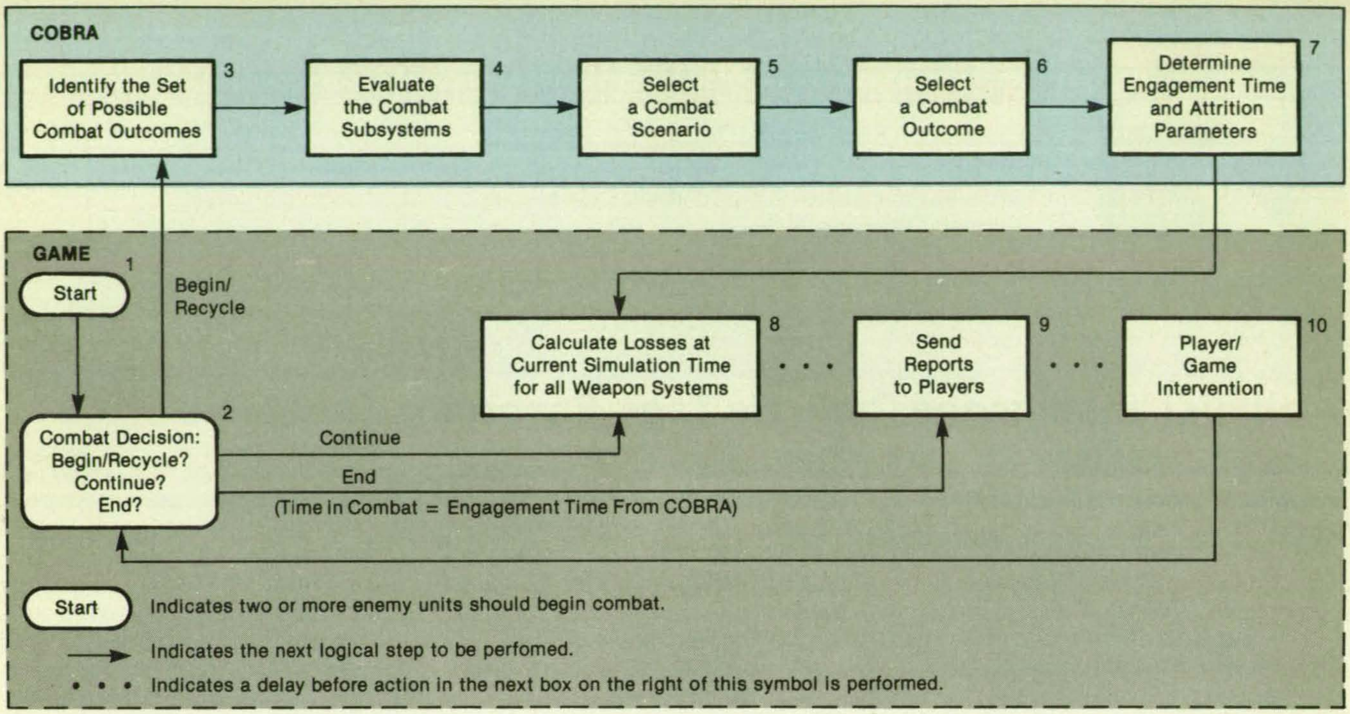
NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed expert system would predict the outcomes of combat situations. Called "COBRA" (combat outcome based on rules for attrition), the system would select rules for the mathematical modeling of losses and discrete events in combat according to previous experiences.

Unlike presently available simulation systems, COBRA would handle a broad spectrum of cases, would require less knowledge of simulation models on the part of users, and would consider other factors in addition to attrition in determining outcome. It would ensure reasonable simulation results, assess missions, and simplify postsimulation analyses.

Although COBRA is intended for the simulation of large-scale military exercises, the concepts embodied in it have much broader applicability. In industrial research, for example, knowledge-based systems would enable qualitative as well as quantitative simulations.

COBRA would be used with another software module known as the "Game" (see figure), which would move units around the battlefield and determine when they have



The **Game/COBRA Software System**, consisting of the Game and COBRA modules, would provide for both quantitative aspects (i.e., detailed losses) and qualitative aspects (discrete events and decisions) in simulations of battles.

entered the combat zones of enemy units. The Game would then invoke the COBRA module and give COBRA data on the units. COBRA would predict the way the engagements should unfold and would record the rules it used in arriving at its prediction. The specific rule trace would be used by the players for analyzing the results.

The prediction of COBRA would hold until a player — human or automated — intervened or until the end of the engagement. At least a few such interventions are likely — the arrival of new forces, changes of mission, or air strikes, for example — and the Game would recall COBRA for a new prediction at each. The Game would calculate losses and report to the players.

This work was done by J. P. Provenzano of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 9 on the TSP Request Card.* NPO-17720

Cleaning Animals' Cages With Little Water

Freezing and thawing may save energy and time.

Marshall Space Flight Center, Alabama

A proposed freeze/thaw method for cleaning animals' cages would require little extra weight and consume little power and water. The cleaning concept was developed for maintaining experimental rat cages on extended space missions. It is adaptable as well to similar use on Earth. The proposed method would reduce cleaning time. It would make use of such already available facilities as refrigerator, glove box, and autoclave.

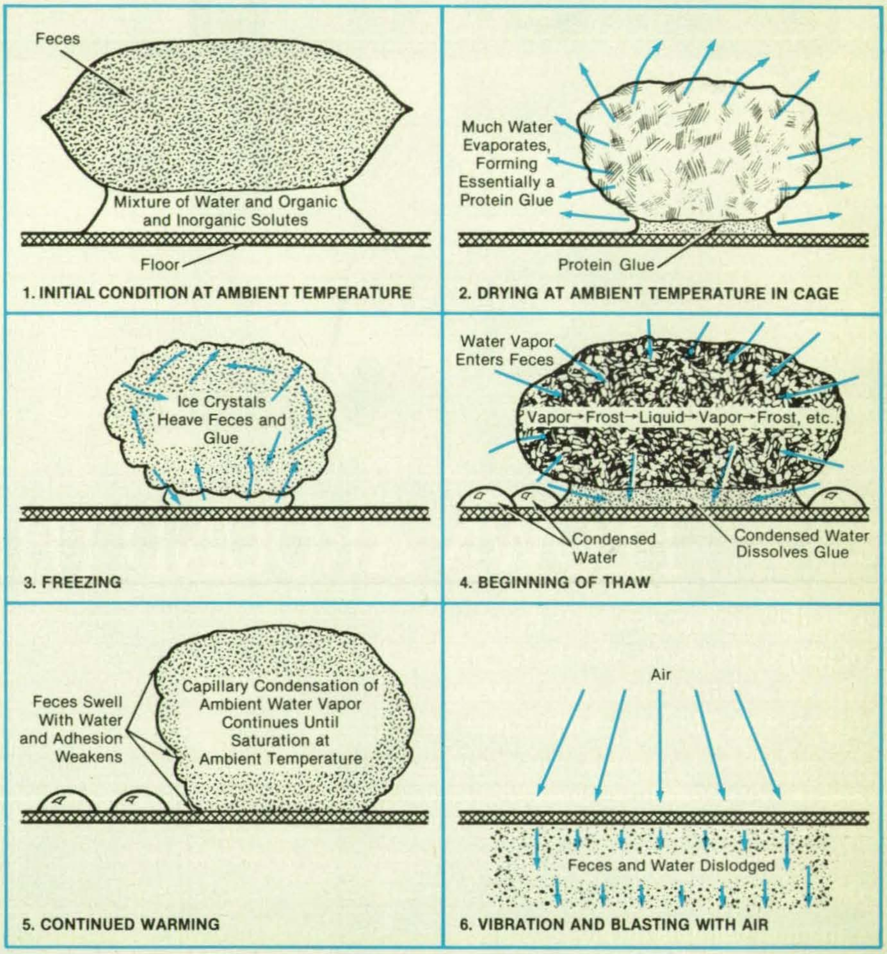
Each cage has a wire-mesh floor through which rat feces and urine pass into a litter pan. Some of the waste gradually accumulates on the wire-mesh floor and adheres to it. From time to time, it is necessary to replace the dirty floor with a clean one from storage. Because the feces adhere strongly to the dirty floor, the conventional practice has been to clean the dirty floor with a blast of steam.

In the new cleaning method, the attendant would first place the dirty floor in a bag, then in a freezer at a temperature of −80 °C. After waiting long enough for equilibration at the low temperature, the attendant would remove the bagged floor, place it in a glove box, and cut a hole in the bag to admit warm, humid air.

Water vapor would enter the microscopic pores of the feces, condensing in the pores and on the floor as liquid water and ice (see figure). The combination of the formation of ice crystals and hydrolysis by condensed water would weaken the adhesive bonds within the feces and between the feces and the floor. The attendant would then remove the loosened feces by blasting them with air while vibrating the floor or by applying an expanding foam.

It may be necessary to heat the floor (possibly in an autoclave) to remove solidified lipids. However, water would probably not be needed. A degreaser and/or disinfectant could be included in the foaming agent or added to the bag in the glove box.

This work was done by Benjamin J. Harman of The Boeing Co. for **Marshall Space Flight Center**. *For further information, Circle 48 on the TSP Request Card. MFS-28275*



Rat Waste Adheres to the steel-wire-mesh floor of a cage. The feces are removed by the loosening action of a freezing-and-thawing process, followed by a blast of air.

Microencapsulation of Living Cells

Walls selectively pass molecules, keeping out harmful substances.

NASA's Jet Propulsion Laboratory, Pasadena, California

In an experimental technique, living cells and other biological materials can be encapsulated within submillimeter-diameter liquid-filled spheres. The sphere material is biocompatible, tough, and compliant. It is semipermeable, permitting relatively

SPECIAL REPORT

The Science of Range-Doppler Imaging

Fundamental range-Doppler radar imaging methods developed at ERIM are providing new capabilities in a variety of applications.

Range-Doppler Imaging

Fine Resolution microwave or laser images of objects which are rotating with respect to the radar system can be formed using the principles of range-Doppler imaging. Range resolution for such a system is provided by ranging with wideband waveforms subjected to pulse compression to accurately measure distance to the scatterers of interest. Cross-range, or azimuth, resolution is provided by performing Doppler-frequency spectral analysis (FFT) within range bins. Signals with higher Doppler frequency content are associated with scatterers of greater line-of-sight velocity which in turn implies increasing cross-range offset from object center. Display of the range bins and Doppler-frequency cells within range bins in a rectilinear grid results in a reflectivity image of the rotating object or scene.

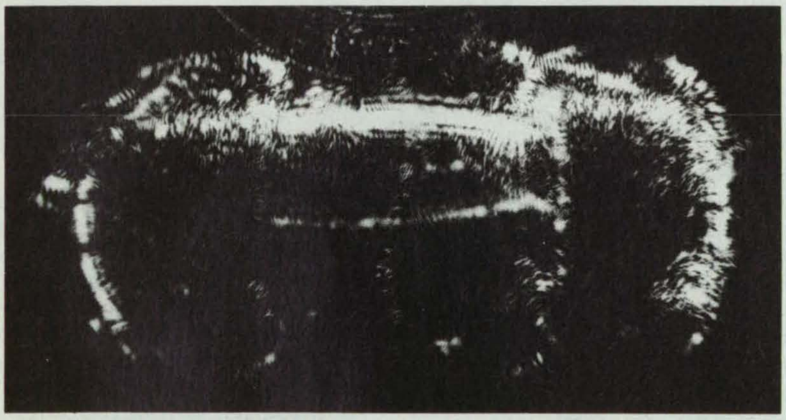
With this approach, finer azimuth resolution is obtained by performing the Doppler spectral analysis over increasing time intervals. However, as one strives for finer resolution, the integration time can become so long that individual scatterers begin to move through the image resolution cells that one is attempting to form. In such a case the resultant image quality actually degrades with increased integration time.

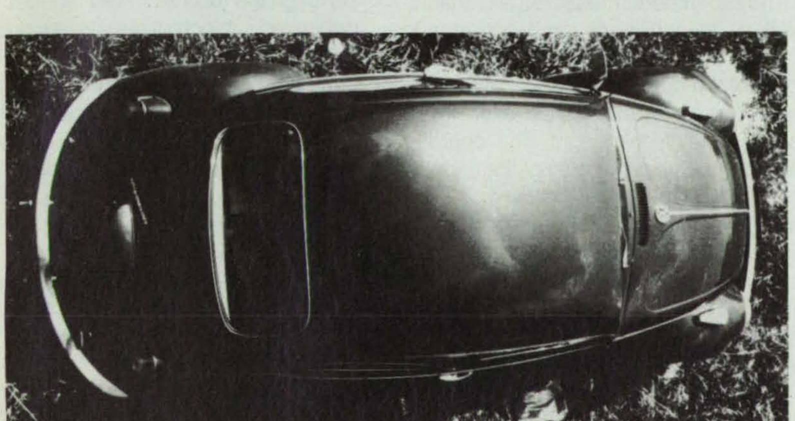
Polar-Format Algorithm

A number of image-formation algorithms have been formulated to compensate for the effects of motion through cells during the integration period. The Polar-Format Algorithm, developed at ERIM for use with our ground-based and airborne imaging radar systems, has become widely noted as an extremely powerful, yet elegantly simple and efficient method of overcoming these previous limits of imaging capability. The images below show a Volkswagon and its associated microwave range-Doppler image processed using the Polar-Format algorithm. This image was produced using the ERIM ground-based, range-Doppler imaging facility.

Applications

Fine-resolution range-Doppler imaging is applicable to a number of situations, including space object imaging (SOI), Inverse Synthetic Aperture Radar (ISAR), and Spotlight-mode SAR for airborne imaging of ground scenes. In principle, the approach is suited to both optical and radar wavelengths. Also, the theory has been extended to allow for three-dimensional imaging of objects given suitable signal collection configurations.





The Environmental Research Institute of Michigan (ERIM) is a scientific research institute that performs contract research services for a variety of sponsors. Our sponsors include government organizations, industry, and universities. Research at ERIM focuses upon remote sensing systems, devices, and techniques that span the electromagnetic spectrum. Within this broad research area, staff members employ their knowledge of modern electronics, optics, computer science, and infrared and microwave physics.

Career Opportunities

ERIM's Sensor Systems Division has immediate opportunities for Research Engineers and Scientists who possess one or more of the following skills:

- **Real-time embedded systems**
- **Software simulation/modeling**
- **Software systems engineering**
- **Digital signal processing**
- **Kalman filtering**
- **Navigation systems software**

All positions require a B.S., M.S. or Ph.D. in electrical engineering, physics, computer science or mathematics, and some relevant experience (2-5 years desirable).

If qualified, please send your resume to ERIM, Human Resources Manager—NT1189, P.O. Box 8618, Ann Arbor, MI 48107-8618. Ask about positions available in Ann Arbor, MI; Los Angeles, CA; Fort Walton Beach, FL; Washington, DC and Dayton, OH.

ERIM

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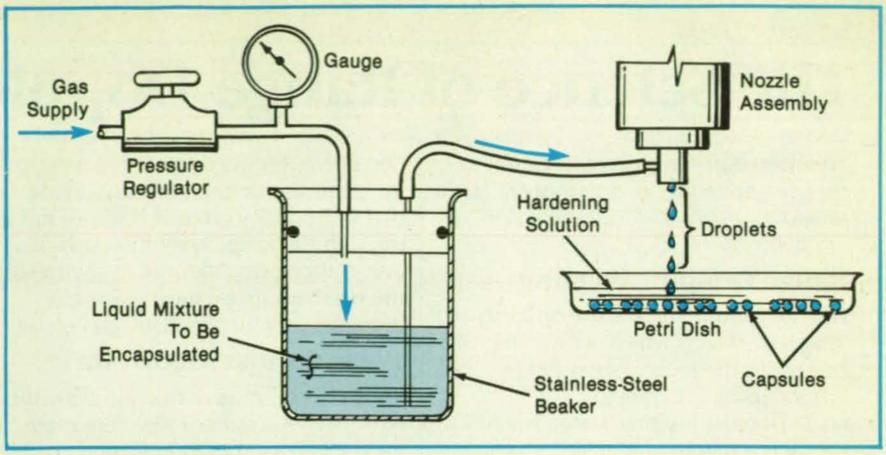
small molecules to move into and out of the sphere core but preventing the passage of large molecules.

A promising application for the technique would be in the treatment of diabetes. In diabetes patients, the islets of Langerhans can no longer generate insulin. In principle, diabetes could be corrected by injecting the islets from another source, such as human donors or pigs, for example, but the human immune system would destroy the foreign cells. If, however, replacement islet cells were encapsulated in the semipermeable spheres, insulin could readily pass from the cores, and nutrients could pass into them. At the same time, antibodies, which are large, would be kept out of the cores so that the cells are protected from the immune system of the host and could live indefinitely in the body.

The new technique promises to make such spherical capsules at high rates and in uniform, controllable sizes. The capsules could be injected into a patient through an ordinary hypodermic needle. It might also be used to encapsulate pituitary cells and thyroid hormone adrenocortical cells for treatment of other hormonal disorders, to encapsulate other secreting cells for transplantation, and to package a variety of pharmaceutical products and agricultural chemicals for controlled release.

The cells to be encapsulated are suspended in a solution of sodium alginate, and the liquid mixture is forced through a fine orifice, forming a jet (see figure). The jet spontaneously breaks up into droplets. To ensure that the droplets are uniform in size, the jet is vibrated at a frequency chosen to overwhelm random fluctuations that would lead to a dispersion of sizes. The droplets fall into a shallow container of Chitosan (or equivalent) solution, which solidifies the surfaces of the droplets, forming a strong, tough skin. (Chitosan is a product of deacetylation of chitin and resembles cellulose structurally except that some of the hydroxyl groups have been replaced by amine groups.)



The **Experimental Apparatus for Making Capsules** is simple. The pressurized liquid is sprayed through a nozzle. The surfaces of the droplets thus formed harden in the petri dish.

The diameter of the droplets is determined by the diameter of the orifice, the speed of the jet, and the frequency of the vibration. At a speed of a few hundred centimeters per second, capsules of 300-μm diameter are produced. One jet can generate several thousand capsules per second.

This work was done by Manchium Chang, James M. Kendall, and Taylor G. Wang of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 73 on the TSP Request Card.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

Edward Ansell
Director of Patents and Licensing
Mail Stop 301-6
California Institute of Technology
1201 East California Boulevard
Pasadena, CA 91125

Refer to NPO-17434, volume and number of this NASA Tech Briefs *issue, and the page number.*

Books and Reports

These reports, studies, handbooks are available from NASA as Technical Support Packages (TSP's) when a Request Card number is cited; otherwise they are available from the National Technical Information Service.

Effects of Vibrations on Grasp Control

Vibration can be a powerful and specific stimulus to low-level reflex behavior.

A report describes experiments on the interactions between human operators and a hand control device for the control of the extent of opening and the gripping force of a remote gripper. The major purpose of this study was to determine the effects of vibrations in the device upon the ability of the operators to control the gripping force.

The control device includes a force-and-position-reflecting trigger mechanism in a housing that fits comfortably in the operator's hand. The opening of the jaws of the gripper is fed back to the operator's hand via the position of the trigger. The position feedback is provided by a dc motor, lead-screw drive, and servoelectronics and computer programs. The gripping force is fed back to the operator's hand by a mechanism that tilts the trigger proportionally. The control signal is the force applied by the operator's finger to the trigger. This force is measured by a strain-gauge bridge, digitized, and sent to the control system of the gripper motor.

The experiments measured two characteristics: the ability of each operator to maintain a constant gripping force and the ability of the operator to produce a specified force as quickly as possible in response to a flashing light. The operator viewed a bar-height display of the gripping force. To characterize the dynamic performance, the experimenters measured the rise times and overshoots of the operator's responses. Measurements were taken with and without superimposing vibrations on the trigger via the force-reflecting mechanism.

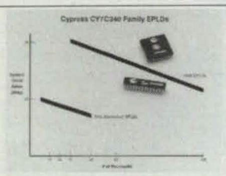
The experiments revealed biomechanical cross coupling between the force-reflecting tilt of the trigger and the control-force sensor through the operator. For some operators, this cross-coupling resulted in oscillations at a frequency of about 1.3 Hz. The oscillations were suppressed when the force-reflecting gain was reduced to less than half its full-scale value.

The experiments also revealed a slowing of the dynamic force-tracking response when vibrations at a frequency of ~300 Hz were included in the position feedback of the trigger. These vibrations provoked a reflexive short-term extension of the finger. Although the extension was reduced in experienced subjects, it remains a significant property of the grasping behavior of humans. While this phenomenon may be detrimental to the rapid application of force commands, it could be used beneficially in the design of controls to provide warning signals that would prevent operators from commanding excessive (or perhaps insufficient) forces.

This work was done by Blake Hannaford and William H. Rosar of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "Some Effects of Mechanical Vibration on Grasp Control," Circle 28 on the TSP Request Card.*
NPO-17698

New on the Market

DAISy, a **computerized flow measurement system** from Analytical Services and Materials Inc., Hampton, VA, identifies and demarcates regions of flow separation, reattachment, stagnation, and laminar-to-turbulent transition simultaneously. It consists of a rack-mounted microcomputer, sensor modules, a power supply, data analysis software, and an optical storage unit with 240MB data storage capability. The diagnostic tool can be used for fundamental research on steady as well as unsteady flow separation and transition. Its small size and portability enables in-flight application.
Circle Reader Action Number 770.



A new family of **CMOS erasable programmable logic devices** (EPLDs) from Cypress Semiconductor, San Jose, CA, matches lower-end gate array densities. The EPLDs fill gate array applications without nonrecurring engineering charges and with a shorter time to market. In contrast to gate arrays, which require weeks or months for design time and prototyping, an EPLD design can be implemented in hours, with modifications possible in minutes. The new ICs are suited for register-intensive applications such as large state machines, video controllers, and network controllers.
Circle Reader Action Number 776.

The Cryocam 80, a **CCD camera system** for low light applications, has been introduced by Micro Luminetics Inc., Los Angeles, CA. The CCD virtually eliminates dark current when cooled to -80° C, enabling exposures of up to an hour. This is achieved without liquid nitrogen or other liquid coolants. The camera features a resolution of 572 x 485 pixels and extremely high sensitivity. Its user-friendly software provides histograms, contrast enhancements, digital filtering, and true or pseudo color for added clarity.
Circle Reader Action Number 800.

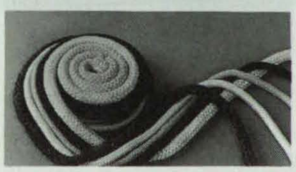
The **Computer Directory** from Ziff Communications Company, New York City, provides specifications for more than 55,000 computer hardware and software products, and profiles the 9500 manufacturers of those products. The online electronic directory contains information on software packages, computer systems, peripherals, and telecommunications products. Users can locate products by company or product name, product type, and price range. The Computer Directory is available through the CompuServe Information Service.
Circle Reader Action Number 778.

Netronix, Petaluma, CA, has introduced an **industry-standard bridge for Ethernet networks**. The EtherMaster™ 13000 bridge combines up to 14,000 packets per second performance with advanced security and administration capabilities. Standard features include the SystemMaster™ Network Management Facility, which enables network administrators to configure the bridge and monitor its status from any network node; selective filtering for better network security and control; and the IEEE Spanning Tree Protocol, which supports complex network configurations.
Circle Reader Action Number 774.

The first "palmtop" personal computer, dubbed the Portfolio™, has been introduced by Atari Computer, Sunnyvale, CA. The one-pound PC, which is slightly smaller than a VHS videotape, accepts adapted MS-DOS software and MS-DOS-compatible commands, and includes built-in Lotus 1-2-3® file-compatible spreadsheet and word processing software, as well as a calculator, an appointment book program, and a phone/address directory with autodialing. Priced at $399.95, the Portfolio has a standard typewriter-style keyboard and is powered by three "AA" alkaline batteries.
Circle Reader Action Number 772.

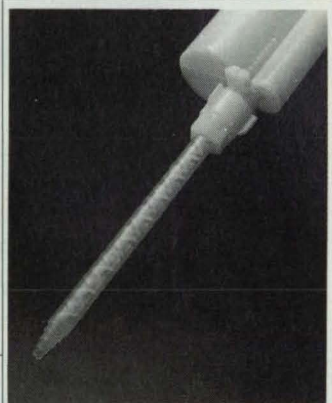
TRANSL8, a **data conversion utility** that allows information to be shared between dissimilar computer systems, is now available from Accelr8 Technology Corp., Denver, CO. The product resolves binary incompatibilities and recreates file organizations when transferring files across a network. After conversion, the file is in the correct format for the target system. TRANSL8 is available on DEC's RISC systems, Sun 3 and 4, SPARCsystems, Silicon Graphics, the IBM RT system, and MIPS computer systems.
Circle Reader Action Number 762.

WaveEdit™ is a **program for reviewing and editing massive files of experimental data stored in Apple Macintosh files**. Developed by World Precision Instruments, New Haven, CT, WaveEdit makes it easy to review data recorded with a variety of acquisition programs and equipment, identify regions of interest, and then cut, copy, and paste those selections to a new file for display and analysis. WaveEdit can open any 12-bit data file that can be saved in simple text or binary format. The program runs on any Macintosh computer with at least one megabyte of memory.
Circle Reader Action Number 758.



Mid-Mountain Materials Inc., Redmond, WA, has introduced a new line of **fiberglass textiles** for use in industrial surroundings where extreme temperature resistance or insulation is required. The HYTEX 1000 products feature high tensile strength, heat protection to 1000° F, and resistance to thermal shock, vibration, and most chemicals. HYTEX 1000 products are available as woven cloth and tape, knit rope, and knit sleevings.
Circle Reader Action Number 764.

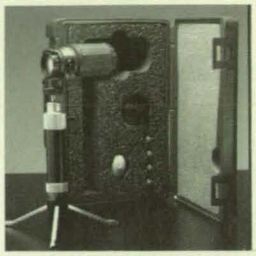
Ross-Hime Designs Inc., Minneapolis, MN, has introduced the **Omni-Wrist** for telerobots, aerospace and aviation inspection, and robotic welding. Originally developed under a NASA Langley Research Center contract for space processing applications, the Omni-Wrist features 180 degrees of singularity-free pitch/yaw motion and 360 degrees of rotation. Remotely positioned drive motors and a 3/4" through hole add to the device's flexibility.
Circle Reader Action Number 768.



Techcon Systems Inc., Carson, CA, has developed a new system called Ratio-Pak™ for **packing, metering, mixing, and dispensing adhesives, sealants, coatings, and potting compounds**. Material is fed from a twin-cartridge through a disposable static mixing nozzle to achieve superior ratio control and easy cleanup without solvent purge. Cartridges are available in 75 to 750 ml capacities.
Circle Reader Action Number 766.

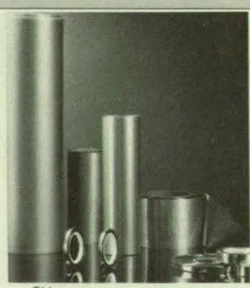
The Sun Maxx from Watersmith Inc., Dallas, TX, is a new **solar-powered battery charger** for 6-, 12-, or 24-volt batteries. The 3"x 6" device uses the sun's power to "trickle" charge batteries in automobiles, tractors, lawn mowers, boats, and airplanes. While most efficient in direct sunlight, Sun Maxx also works in low light or shade. It consists of a weather-resistant solar panel and a cigarette lighter connector, or alligator clips for direct hook-up to the battery.
Circle Reader Action Number 760.

New on the Market



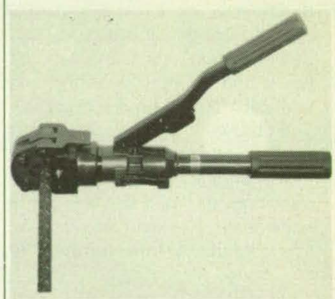
The NIRSCOPE™ 1500 from Quantex Corp., Rockville, MD, is the first **handheld infrared (IR) viewer** for the 1.0 to 1.6 micron range. Using an upconverting phosphor screen coupled with an image intensifier tube, the NIRSCOPE has a gain 1200 times that of standard photocathode image converters, according to the manufacturer. Laboratory technicians and engineers working with 1300 nm to 1500 nm fiber optics and laser systems will now be able to view lower wavelength signals. Applications include laser beam alignment, fiber optic coupling, fiber continuity tests, laser detection, and night scene viewing.
Circle Reader Action Number 752.

The ViewPoint Machine Translation Interface (VP-MTI) from the Xerox Corp. **translates entire documents** while retaining charts and graphics in their original form. This capability is significant in the foreign language technology market because users will no longer have to recreate graphics after machine translation. The VP-MTI software, which can translate English into German, French, Spanish, Italian and Portuguese, provides an interface from Xerox 6085 workstations to an IBM-compatible mainframe computer running customized Xerox applications software and SYSTRAN translation software.
Circle Reader Action Number 754.



Danar™ 1005, a heat-resistant **amorphous thermoplastic film**, is available from The Dixon Division of The Fluorocarbon Company, Bristol, RI. Produced from General Electric's Ultem® 5001 polyetherimide resin, Danar 1005 resists most industrial solvents, exhibits dielectric strength up to 7000 volts/per mil for greater insulation value, and has a continuous operating temperature as high as 400° F.
Circle Reader Action Number 746.

3M Fiber Optic Laboratories, St. Paul, MN, has developed a series of low linear birefringence **single mode fibers** for high-sensitivity sensing systems. The fibers can detect changes in the polarization of linearly polarized light travelling in the fiber core, such as in magnetic field sensors that measure field strength as a function of polarization rotation due to the Faraday effect. Fibers are available for transmission at 500, 630, and 850 nm.
Circle Reader Action Number 748.



The JSH-20 **hydraulic rebar/wire cutter** from Huskie Tools Inc., Glendale Heights, IL, quickly and safely cuts 3/4" wire rope and soft steel bolts, 3/4" ASCR cable, 9/16" EHS guy wire, and 5/8" ground rod. The JSH-20 features replaceable blades that can be changed in the field, reducing downtime and providing a cost savings over non-reusable bolt cutters. The new cutter can replace an entire tool kit, including various sizes of conventional bolt cutters, hacksaws, and cable cutters.
Circle Reader Action Number 750.

Hewlett-Packard Company, Cupertino, CA, has developed a product that enables computer users in a UNIX environment to perform full-text keyword search and retrieve customer-support information from a CD ROM (compact-disc read-only memory). Called HP LaserROM/UX, the **retrieval software** lets users simultaneously access the equivalent of more than 20,000 pages of on-line information related to the operation of HP 9000 Series 300 and Series 800 HP-UX computers. The HP-UX operating system is based on and fully complies with AT&T's UNIX system.
Circle Reader Action Number 756.

New Literature

A free brochure from Connector Accessories Inc. (CAI), Middlefield, OH, displays custom-designed **cable and wire assemblies for voice, data, and power transmission**. The six-page brochure details CAI's engineering and production capabilities, which include injection, insert, transfer, and shuttle molding; crimping multi-diameter wire and cable; and automatic wire cutting and stripping. CAI can design and construct assemblies to incorporate virtually any UL or CSA connector and meet industrial as well as military specs.
Circle Reader Action Number 712.

Concurrent Computer Corp., Westford, MA, has published a new brochure describing its real-time **UNIX and OS/32 operating system products**. The brochure covers system integration capabilities and features short stories on aerodynamics and plant control applications.
Circle Reader Action Number 710.

Reid Tool Supply Co., Muskegon, MI, has published a 306-page **tool room equipment catalog** featuring knobs, handwheels, clamps, ball and spring plungers, tooling components, setup accessories, leveling pads, and other standard parts. New products include Mitutoyo and Starrett precision instruments, locating pins, hold down clamps, De-Sta-Co clamps, mist cooling systems, air tools, end mills, and cutting and tapping fluids. Prices and specifications are included for each item.
Circle Reader Action Number 704.

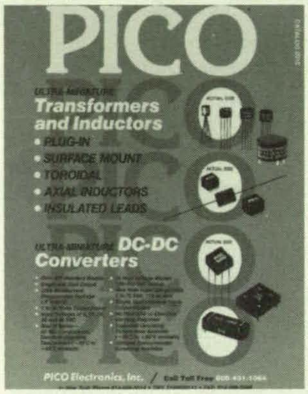
A 600-page **directory detailing the space activities of more than 35 countries**, from Argentina to the USSR, is available from Jane's Information Group, Alexandria, VA. The Space Directory covers national industries — highlighting individual companies and their current work — and describes US/Soviet competition in developing space stations, manned spacecraft, and launchers. Space logs, flight manifests, and satellite tables are provided, as well as addresses and telephone numbers of aerospace contractors.
Circle Reader Action Number 702.

Valcor Engineering Corp., Springfield, NJ, is offering a free brochure on **aircraft/aerospace fluid control products** and their applications. The brochure provides technical data on solenoid valves, relief valves, pressure regulators, self-displacing hydraulic accumulators, composite and single-element pressure vessels, and pressurization systems. These products are used to transfer aircraft fuels, to control deicing systems, and to handle corrosive fluids. They also help keep electronics cool, maintain cabin pressures, and control wheel brakes and other pneumatic and hydraulic systems.
Circle Reader Action Number 706.

A 64-page catalog of **technical publications and computer software** is available free of charge from Cole-Parmer Instrument Co., Chicago, IL. Book offerings include: The Hazardous Chemicals Desk Reference; Chemical Technicians' Ready Reference Guide; the Merck Index; Hawley's Condensed Chemical Dictionary; and Practical Statistics for Analytical Chemists. Software selections include: GANTT® Lab Manager; LSTAR® project management software; TECHWRITER® for scientific word processing; and ASYSTANT+® for data acquisition and analysis.
Circle Reader Action Number 708.

New Literature

X-band microwave amplifiers and systems are illustrated in a four-color brochure from MCL Inc., Bolingbrook, IL. Designed for small communication satellite ground terminals, the amplifiers operate in the 7.9 to 8.4 GHz range, with output power of 90 to 2500 watts. The brochure describes both TWT and Klystron amplifiers, providing specifications for each unit.
Circle Reader Action Number 714.



Over 3000 **transformers, inductors, and DC-DC converters** are featured in a new catalog from Pico Electronics Inc., Mt. Vernon, NY. Model series include ¼"x ¼" surface mount, plug-in, toroidal, axial inductors, and insulated leads. The DC-DC converter section details over 850 standard single, dual, and triple output models. Regulated and isolated units are rated to 30 watts with input voltages of 5, 12, 24, 28, and 48v DC.
Circle Reader Action Number 720.

"Nyliner News," an eight-page newsletter published by Thomson Industries Inc., Port Washington, NY, describes typical applications for Thomson's **injection-molded Nyliner plastic bearings**. The newsletter features new product information and updates on installation techniques. Readers are offered a free bearing application kit containing samples of standard Nyliner bearings.
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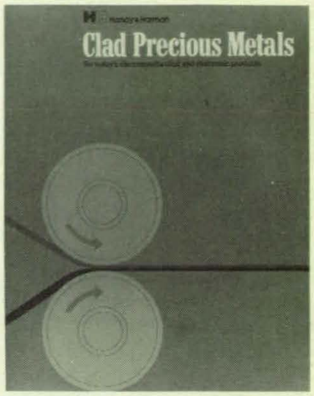
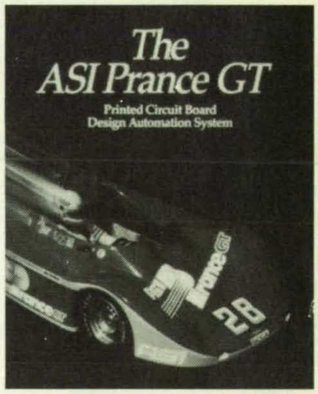


Handy & Harman, New York City, has produced an 18-page brochure on **clad precious metals for electromechanical and electronic products**. Available free of charge, the brochure describes the clad precious metal manufacturing process and includes typical configurations and specifications for overlays, inlays, contact welding tapes, solder prints, and braze bonds. A base metal alloy guide details the physical and mechanical properties of pure metals and alloys used in clad metal products.
Circle Reader Action Number 716.



A four-color brochure from Automated Systems Inc. (ASI), Brookfield, WI, describes Release 2.0 of the Prance GT™ **printed circuit board design automation system**. The brochure depicts the system's SX™ and Warp Grid™ design automation techniques, open engineering configuration, and routing, output, and documentation features. Software support and training provided by ASI are also covered. The brochure includes benchmark results on dense, ECL fineline board designs.
Circle Reader Action Number 722.

Epoxy and urethane resin systems are discussed in a new catalog from the Hexcel Corporation, Newbury Park, CA. The publication highlights the handling and physical properties of structural adhesives, surface coats, laminating systems, epoxy casting compounds, casting elastomers, and ancillary materials.
Circle Reader Action Number 724.

Subject Index

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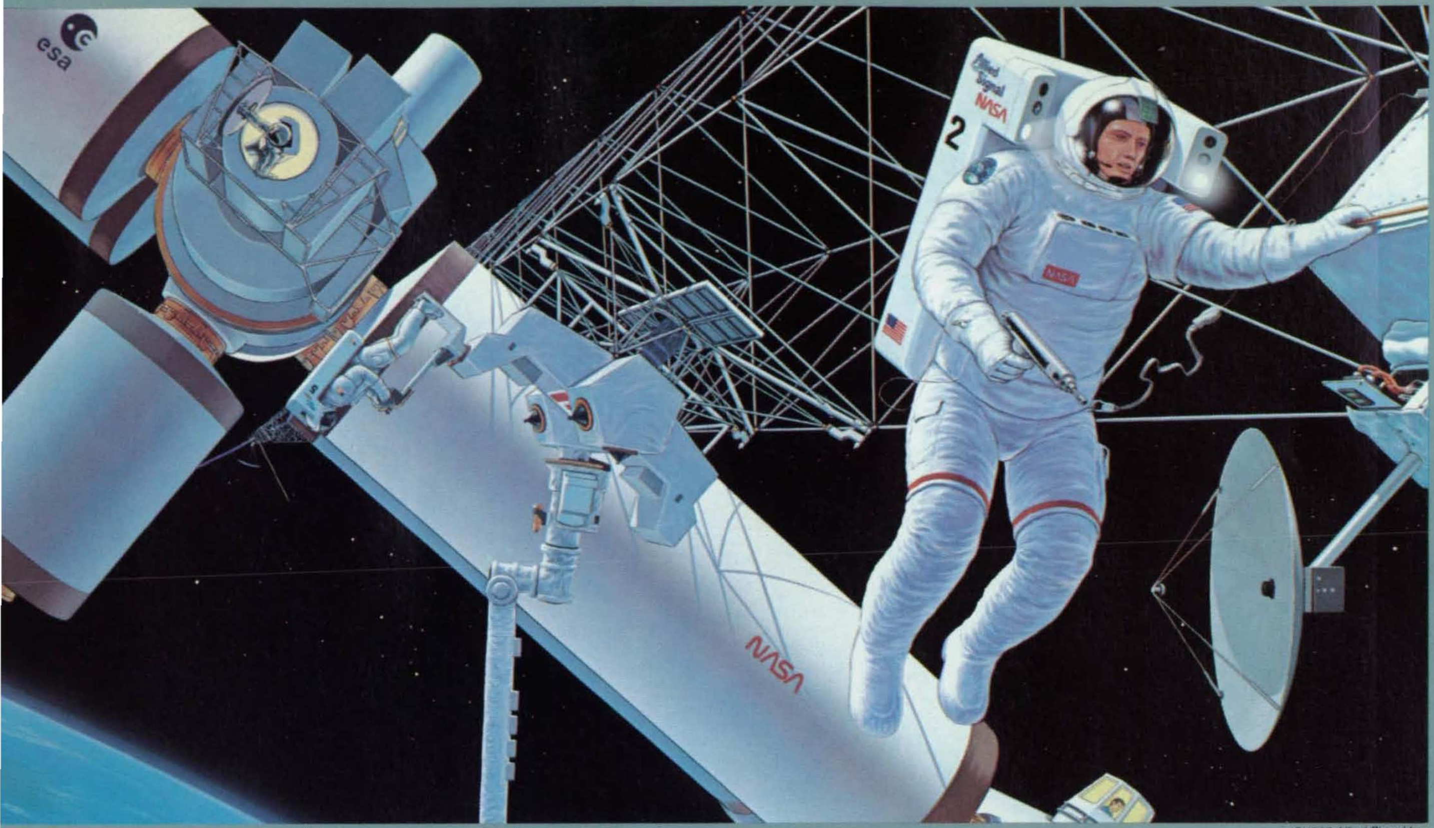

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—Ken Davis (far right), RAPIER Intelligence Segment (RIS), RIS Program Manager Electronic Systems with (from left to right) Dick Elsey, RIS Technical Staff, Jim Dellinger, RIS Technical Staff, Ray Marion, RIS Technical Staff, Bill Blatchley, RIS Technical Staff, Jim Pierce, RIS Software Development Manager.

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